POWER

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WHEN "DAD" GOES AFTER THE CHIEF'S JOB

Practical Refrigeration for the Operating Engineer —Getting Acquainted with the Plant

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WHEN once the engineer has the operation of the compression system of refrigeration as securely fixed in his mind as he has the steam plant, he will make a long step toward a better understanding of both systems, together with better results.

The actual operation of the compression system is so nearly like that of the steam-boiler plant, where the latter is in connection with a compound condensing engine, that when one system is thoroughly understood it is easy to understand the other, as the two are based on the economical evaporation and use of two liquids, one of which is evaporated to produce power and the other to produce refrigeration. Fig. 1 shows a small ice plant.

There are many engineers who appreciate this similarity of operation and are thoroughly familiar with the two systems. But as I have found many more, especially among the younger engineers and some of the older ones, who do not understand, this and other articles to follow will make comparisons and give experiences intended for the engineer who has not had the advantage or the years of experience in connection with the operation and correction of refrigerating-plant troubles.

With a steam boiler or steam-generating plant in connection with a compound condensing engine the water is pumped into the boiler and evaporated into steam by means of heat from the fire in the furnace. The steam is carried at a pressure ranging from 5 lb. to more than 250 lb. per sq.in. The steam is delivered to the engine in a saturated or superheated condition through the high-and low-pressure cylinders and from there to a surface steam condenser, where it is condensed to water and pumped back into the boiler. If there were no losses of water due to leakage, the same water could be used indefinitely. Now follow the compression system of refrigeration through a similar circuit, starting at the boiler for the liquid anhydrous ammonia. Suppose we place the liquid ammonia in the evaporating, or so called expansion, coils. The heat from the brine or surrounding temperature of the room, as the case may be, on the outside of the coils will evaporate the liquid ammonia to a saturated gas which passes from the evaporating coils to the compressor, through the compressor cylinder to the ammonia condenser, where the gas is condensed back to liquid, and from the condenser the liquid is carried back to the evaporating coils ready to be fed into them and start another complete circuit. If there were no losses due to leakage, etc., the same liquid ammonia could be used indefinitely.

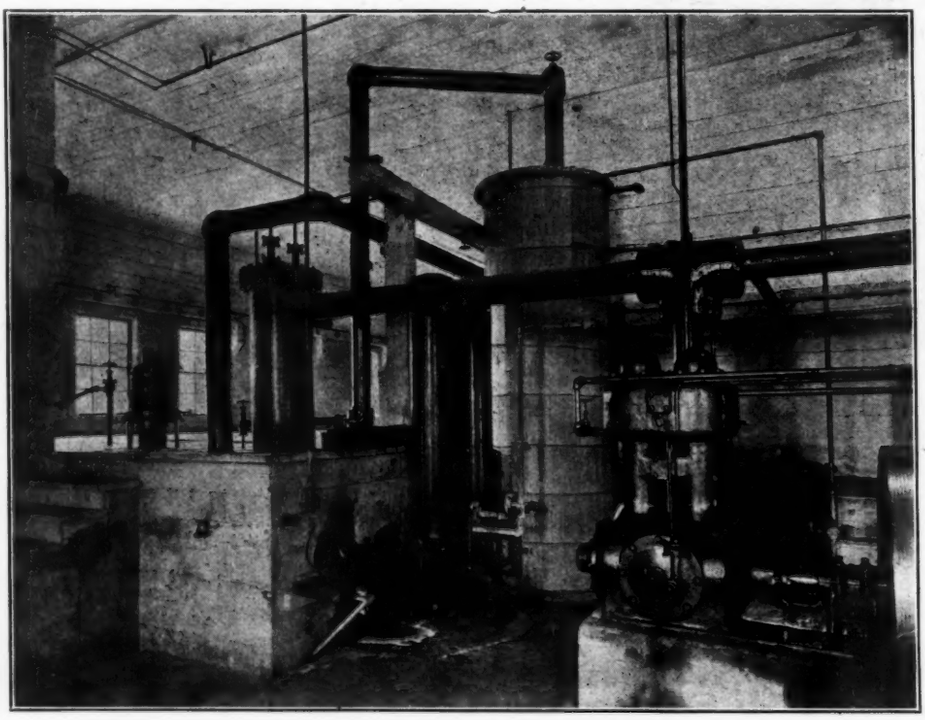


FIG. 1. A TEN-TON RAW-WATER, FLOODED-ICE PLANT, YORK TYPE, AT WILSON, ARK.

So far as a point of operation is concerned, there is not much difference. One is a transfer of heat to produce power, and the other is a transfer of heat to produce cold.

When speaking of boiling points or heat, we unconsciously compare the term with something that has a higher temperature than the body, or to the sense of touch, but all temperatures *above* 450 deg. F. below zero, which is absolute zero, are designated by science as degrees of heat. It is easy to understand that the boiling points of liquid refrigerants are cold. The boiling point of liquid air is 312 deg. F. below zero, and science has not as yet discovered anything with a boiling temperature low enough to freeze it. We might consider that the boiling points of various liquid refrigerants range in temperature anywhere from 312 deg. F. below zero to 40 or 50 above; but as we are considering ammonia only, we will confine ourselves to this refrigerant.

With any liquid that boils under all ordinary temperatures and pressures where refrigeration is required, it is necessary to confine the gas (after being evaporated) under pressure and apply cold water to convert it back to liquid so that it may be again evaporated by taking up heat from surrounding brine or air. Ammonia being a liquid that boils at 28½ deg. below zero under atmospheric pressure, it is

necessary to use a condenser. These condensers are of many types and designs the same as steam condensers, and are following the same lines of development as the latter. Fig. 2 shows an atmospheric flooded-type condenser. To further consider from an operating standpoint, let us assume that the ammonia gas has gone through the process of liquefaction and is ready for use as a refrigerant. Suppose we now feed the liquid ammonia into a set of coils placed in an insulated tank and submerged in salt brine. The boiling point of the liquid ammonia entering these coils will vary in temperature with the rise and fall of pressure, the same as the boiling point of water under different pressures. It is necessary only to consult the tables in either case for the properties of saturated ammonia or steam. Assume that the brine surrounding the ammonia coils is at a temperature of 20 deg. F. and that the liquid ammonia and gas inside the coils are under a pressure of 15 lb. Then, by consulting the tables it will be found that the ammonia will boil at about 0 deg. F., which is 20 deg. F. *below* the temperature of the brine; or in other words, if the brine is 20 deg. F. *above* the boiling point of the liquid ammonia, the ammonia will readily be evaporated into a gas the same as water when fed into the boiler to be evaporated into steam.

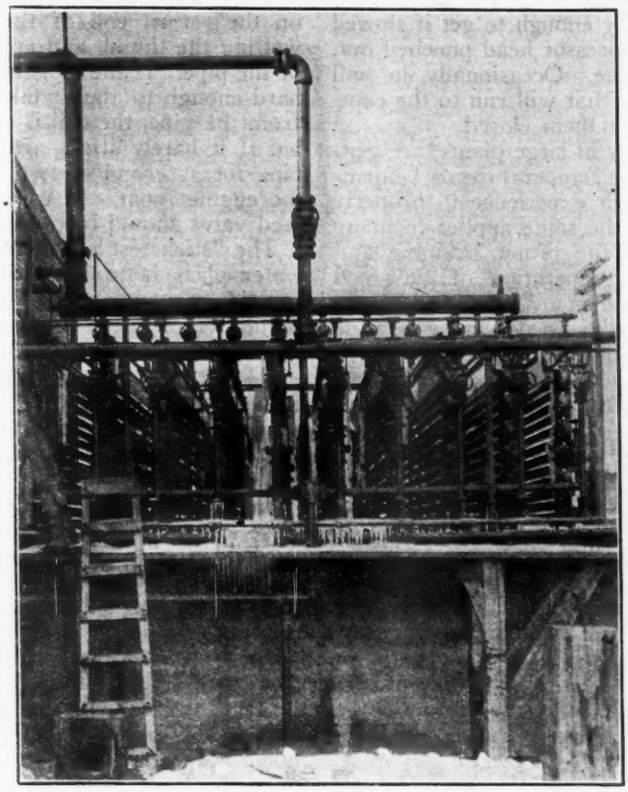


FIG. 2. FLOODED AMMONIA CONDENSER, YORK ATMOSPHERIC TYPE, AT PHILADELPHIA

The various types of evaporating coils or brine coolers are as numerous as the types of steam boilers, but the only kind we will consider at present is the old type with the submerged coils in an insulated tank. The brine tank is insulated to save heat through radiation the same as the boiler walls, steam piping, etc., which are insulated for the same purpose. The brine on the outside of the coils, being at a temperature of 20 deg. F., has the same function to perform as the fire in the furnace in evaporating the water, and as the brine is 20 deg. F. above the boiling point of the liquid ammonia, the ammonia is evaporated into a saturated gas which is taken by the compressor and delivered to a set of coils (the condenser) under a pressure of 150 to 185 lb. These coils are supplied with condensing water ranging in temperature from 50 to 70 deg. F. ordinarily, which condenses the gas back to a liquid which drains from the coils to a tank below the condenser coils, called a liquid receiver; from the receiver it is ready to be delivered to the evaporating or brine cooler and is now ready to be reëvaporated. In the operation of the feed valves, or so-called "expansion valves," which regulate or feed the liquid ammonia into the evaporating coils, it is important that the engineer should not try to force the temperature of the brine down by feeding too much liquid into the coils, as the effect would be the same as trying to raise steam in a boiler by opening the feed valve till the water carried over to the engine cylinder. Many a compressor head has been knocked out by this process of operation.

The liquid in the coils at 15 lb. back pressure is boiling at about zero degrees F., and the amount of liquid that can be evaporated will depend on the evaporating surface of the coils (heating surface), difference in temperature between the boiling liquid inside the coils, the temperature of the brine outside, and the rate of circulation of the brine.

To prevent the liquid ammonia being carried over to the compressor, the engineer or "temperature man" should watch the outlet or return end of the coil or coils, if possible, and not depend on guesswork or wait until the compressor shows signs of distress by the valves pounding, discharge getting too cold, or until the compressor gets a "slug" and raises the engineer up on his toes and his hair on end while

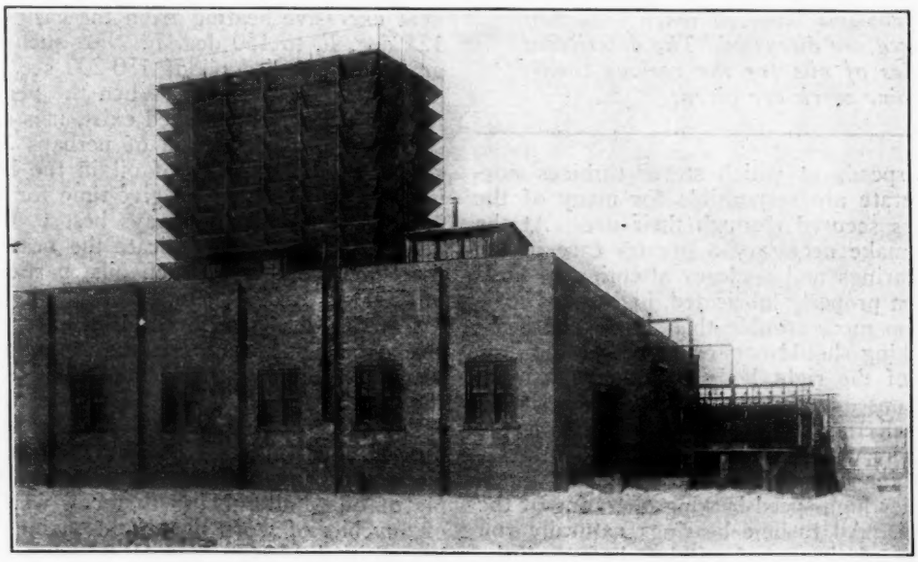


FIG. 3. EXTERIOR OF A 75-TON ICE PLANT, PHILADELPHIA

he makes a mad rush for the throttle. By the time he reaches the engine and is lucky enough to get it slowed down without having the compressor head punched out, he generally finds himself alone. Occasionally, he will find one of the old-time oilers that will run to the compressor suction valves and get them closed.

Cases of this kind, especially in large plants, are generally due to the fact that the temperature or "expansion" man has not had enough experience to properly operate the feed valves, and the same applies to many engineers who have not had the proper training and experience; and although the operation of the feed valves is simple, I have found many young engineers and some of the older ones who do not know how or where to look for a valve that is feeding too much liquid and is "freezing back" too strongly, and will cut back on all the valves (where there are a number leading into one suction line) to get the right one, and in this way it is easy, and it generally is the case that several valves are cut off that are not freezing through the coils. Fig. 3 is an exterior view of a 75-ton plant.

If the engineer of a steam plant is getting a dose of water, he will hurry to the boiler room to see if the watertender is carrying the water too high. He has only to look at the gage-glass, which shows him the water level, but it is different in feeding the evaporating coils with liquid ammonia, as there is no glass to show where the liquid stands in the coils; but if the engineer will clean off a small place on the outlet or return end of each coil, after he has scraped the frost and ice off down to the clean iron surface, he can apply the "stick test," which is simple and effective. He can regulate the feed to the limit on any one or any number of coils without endangering the compressor, and besides, he can run the plant up to the limit of capacity so far as the evaporating coils are concerned.

The "stick test" is applied by cleaning a small place on the return end of the coil, as already explained, wetting the thumb and applying it to the clean surface of the pipe. If the moisture freezes instantly and sticks hard enough to almost take the skin off when removed from the pipe, the coil is freezing back to the machine, but if it barely sticks after holding the thumb on the pipe for a second or two, it is not doing any harm in the engine room. In case there is no stick at all, the feed valve should be opened a little more.

The "stick test" is to the evaporating coils what the water glass is to the steam boiler, and with a little practice, it may be made almost as effective in the proper regulation of "slugs" or overfeeding of the evaporating coils.

Do not try the stick test twice in the same place without first cleaning the pipe surface, as there will be a thin skin of ice left on the pipe from the freezing of moisture on the thumb, which acts as an insulation and will not give a good test.

The coils that generally give the most trouble are those located in a room where the lowest temperatures are held, such as sharp freezers (where direct expansion is generally used), which are carried at a temperature of zero to 20 deg. below, or storage coolers, which are held around 5 to 10 deg. above zero.

There is more danger from "slugs" in direct-expansion quick-freezers than from any other source, due to the fact that the liquid ammonia evaporates very slowly, and for this reason the coils often fill up; then the ammonia is referred to as being "sluggish" or of an inferior quality, or is "hiding out," "lost," etc., when in fact, the sharp or low-temperature freezer coils evaporate the ammonia so slowly that they fill up with liquid ammonia and in many cases will rob the rest of the coolers of the liquid they should get.

Steam-Turbine Lubrication

By W. F. OSBORNE

Discusses the lubrication problems presented by the high speeds and high bearing temperatures met with in steam turbines. As most of the larger turbines are equipped with oil-circulating systems, the layout and operation requirements of such systems are considered. The extra problems involved when reduction gearing is used are discussed. The description and viscosities of oils for the various conditions of turbine work are given.

THE high speeds at which steam turbines normally operate are responsible for many of the advantages secured through their use. At the same time they make necessary a greater care in the design of the bearings and a closer attention to their lubrication. When properly lubricated, high-speed bearings will cause no more trouble than low-speed bearings, but if anything should occur to prevent the flow of sufficient oil of the right body they may burn up very quickly. Consequently, the greatest care should be exercised in selecting turbine oils and in taking the proper care of them while in use.

Ring-oiled turbine bearings are no harder to lubricate than any other high-speed bearing operating at the same temperature. All turbine bearings naturally run warm on account of the speed of the shaft and the radiated and conducted heat from the turbine casing. On some of the smaller turbines which have the bearings located very close to the casing, they may get as hot as 250 deg. F., which, of course, thins down any oil that is used.

To reduce these high temperatures, the bearings are usually water-jacketed, and when so located as to prevent excessive heating from the casing they run from 125 deg. F. to 150 deg. F. For such turbines a high-grade light-bodied oil of 150-200 sec. viscosity at 100 deg. F. is about right. When the very high temperatures previously mentioned exist, it is sometimes necessary to use a heavier oil of perhaps 300-500 sec. viscosity, as the quantity of oil in the bearing reservoir is not usually enough to give time for very much cooling of the oil. It is always best to use the thinnest-bodied oil that will lubricate the bearings, because of the lower friction of such oils, particularly at speeds of 3,000 to 10,000 r.p.m.

Practically all steam turbines except those of small size are equipped with continuous circulating oiling systems. A pump geared to the turbine shaft supplies all the bearings with oil under a pressure varying from 2 lb. to 15 lb. per sq.in., depending upon the type of the turbine, although vertical turbines have much higher pressures. This pressure insures an ample supply of oil to all rubbing surfaces, washing them clean of any bits of worn metal and cooling them by carrying away the heat. The oil pump is always provided

with a bypass with which the pressure and the quantity of oil going to the bearings may be controlled—a very valuable feature if it should be necessary to increase the flow of oil to a hot bearing.

These circulating systems are carefully inclosed to prevent splashing of oil from the turbine and to keep out all foreign matter. Any small bits of grit carried by the oil between the rubbing parts at high speeds could cause a lot of trouble very quickly. The oil drained from the bearings flows to a catch tank, thence through a cooler consisting of a number of coils of pipe in which cool water is circulated to absorb the heat taken up from the bearings.

The temperatures to which the oil is heated in the bearings frequently range from 150 to 175 deg. F. Heating to these temperatures causes the lighter portions of the oil to vaporize and in addition slowly decomposes the oil. Although the system may be ever so carefully inclosed, part of the vapor gets away and the viscosity of the oil remaining in the system is increased. The rapidity of this thickening depends a good deal upon the quality of the oil, the temperature, the amount of agitation and the length of service. Properly refined oils having a minimum evaporation will last a long time without a serious increase in viscosity, and there are records of turbines operating for years on the same oil, only a small amount being added from time to time to make up for evaporation and leakage.

Turbine Oils Grow Dark with Use

All turbine oils change in color, growing darker with use because of slow oxidation or decomposition at the temperatures to which they are exposed. This change in the oil is more noticeable in the pale oils than in the red oils, although the physical change in the latter is equally great.

The engineer may now ask, and quite properly: "How long should the oil remain in the system? How can I tell when to change it and what will happen if I don't?"

It is, of course, manifestly impossible to lay down any fixed rule about the length of time a turbine oil should be used because there are so many sets of operating conditions, all affecting the oil. If samples are taken from the system at regular intervals of two or three months and analyzed for oleic acidity, it is sometimes possible to foretell when the oil is reaching the limit of its usefulness. Oleic acid is caused by decomposition of the oil, the decomposition being accompanied by a very marked tendency to emulsify. As long as the samples show a slow uniform increase in acidity, the oil may be used with safety, but as soon as the increase becomes more rapid, the wise engineer will take out at least a portion of the oil and replace it with new. By this method the consumption may be reduced to a minimum without any danger of the oil being held in service so long as to cause trouble through emulsification. The amount of oleic acid can be determined only by laboratory tests. A description of the method of making these tests is given in Archbutt and Deeley's "Lubrication and Lubricants," on pages 241-2.

Emulsification Troubles

As previously stated, oil that has been used too long may emulsify if a small quantity of water should get into it from leaking cooling coils or from steam blowing through the turbine-shaft stuffing-boxes. High-grade new oils and pure water, however well mixed, will separate cleanly if given an opportunity. If some impurity, such as a small amount of alkali or boiler compound, is added to the water, a thorough agitation such as the oil receives in a turbine circulating system will form a mixture which does not separate as readily. If in addition, the oil is impure, through not being properly refined or from being used too long, an emulsion will be formed which is very difficult to break up. On being circulated through the system, this mixture gradually picks up foreign matter and more water, increasing in volume and becoming very thick—so thick and heavy sometimes that it clogs up the oil pipes and bearing grooves. Boiler compounds carried into the oiling system by steam leaks through stuffing-boxes are a common cause of this sort of trouble.

These emulsions are difficult to break up, although it can be done sometimes by drawing off a portion of the oil and heating it before settling. It is therefore of the greatest importance to secure the very best quality oil and to exercise the greatest care to prevent foreign matter of any kind getting into the system.

A very common source of trouble with turbine oiling systems is the small capacity of many installations. The force-feed pump geared to the turbine drives the oil through the system very rapidly and thoroughly mixes with it any impurities that may not have settled out when the oil was in the reservoir or coolers. The quality and life of the oil many times can be improved by increasing the volume of oil in the system through the addition of storage tanks or filters in which part of the oil may be brought to rest and the foreign matter allowed to settle out. Some oils have the necessary characteristics which permit them to be cleaned even when circulated at high speeds; other oils can be used only when the system contains enough oil so that each part of it reaches the bearings only a few times per day. This increased volume also allows the oil to cool off, thereby lowering the temperature of the bearings and decreasing the rate of evaporation. All these things naturally improve the quality of the oil and increase its life of good service.

Sometimes the oil in a circulating system will begin to foam for no apparent reason and will overflow the reservoir, spilling onto the engine-room floor. This foaming may be caused by water getting into the oil and being churned by the rapid circulation through the pump. If the water does not have a chance to separate so that it may be drained off, the total amount of the mixture of water and oil will soon become larger than the capacity of the system, and it overflows. The remedy is to keep the water out or to increase the capacity of the system by adding a separate tank into which a part of the oil can be removed from the system periodically and the water separated.

Leaking Oil Causes Foaming

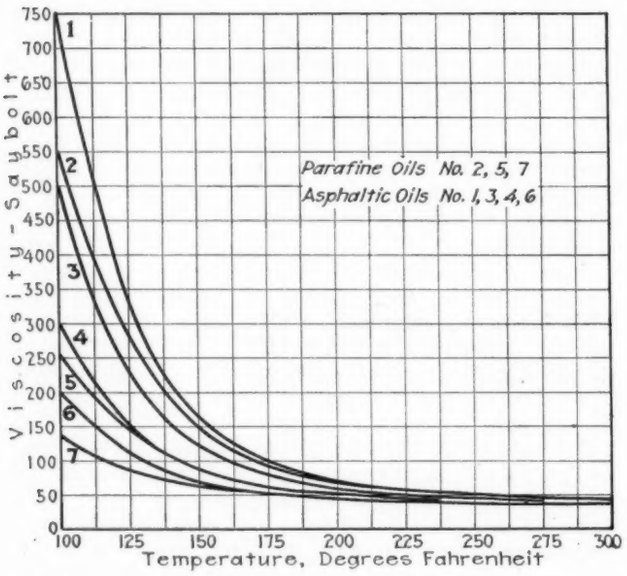
Air getting into the system through leaks in the pump suction or forced into the bearings by the ventilating system of an electric generator will also cause foaming. When this air is churned up with the oil, minute bubbles are formed which do not separate quickly and may increase the volume of the oil in the system sufficiently to cause it to overflow. Sometimes the drain lines are too high above the oil level in the reservoir so that the fall of the oil into the reservoir is sufficient to cause a foam that rapidly accumulates. In either case, when the air is released it carries with it some oil vapor, thus increasing the evaporation and deterioration of the oil.

Deposits in coolers, on bearings and in oil lines are caused principally by the use of oils unsuited to the high temperatures and the agitation to which they are subjected. Oils that have not been highly refined and carefully filtered to remove any foreign matter or heavy

hydrocarbons, that might decompose, will sludge or throw down a heavy slimy substance. If oils are used too long, the same sort of sludging is sometimes observed. When these deposits form on the coils of the cooler, they act as an insulation, greatly reducing the efficiency of the cooler and raising the temperature of the oil in the system. This necessitates a thorough cleaning of all the pipes and tanks.

Hot turbine bearings may be caused by lack of lubrication through stoppage of the oil lines or oil grooves or a failure of the pump. Sometimes they run hot because the clearance along the side of the bearing is not large enough to allow the oil to be carried between the working portions of the surfaces. In other instances too heavy an oil or an oil thickened through long use or partly emulsified will cause this trouble. Permanent temperature reductions may be made only by locating the true cause and applying the proper remedy.

When reduction gear drives were added to steam turbines, an entirely new demand was placed upon the oil.



VISCOSITIES OF SOME WELL-KNOWN TURBINE OILS

The pressure per square inch on the teeth of the gears is many times greater than the load on any bearing, so that heavier-bodied oils are necessary to prevent a breakdown of the film and wear of the teeth. Furthermore, unless the gears are carefully made and lined up, there is a great likelihood of there being some noise as they mesh. Steam-turbine reduction gears are of the herringbone type which reduces the noise to a minimum, and when lubricated with a sufficiently viscous oil they should be comparatively quiet.

The reduction gears are usually inclosed within an oil-tight casing, and the gear bearings are so arranged that the oil draining from them goes into the gear case. On this account it is necessary to use to lubricate the gears something that can also be used on the bearings without causing trouble. When the gears and their bearings are isolated from the steam-turbine oiling system, it is possible to use a heavy-bodied oil of the proper viscosity to take care of the gears. On such installations a pump is provided to take the oil from the gear case and deliver it under pressure to the bearings and spray it onto the gears at the point of meshing. In this way there is nothing to affect the oil except the temperatures within the gear case, and a heavy-bodied oil can be used for a long time without any trouble.

A very common practice, however, is to include the lubrication of the gears and gear bearings in the circulating oiling system for the turbine bearings. These bearings normally require a light-bodied oil, and an exceptionally viscous oil will cause them to heat excessively. Moreover, the heavy-bodied oils do not separate from water and foreign matter as readily as the lighter oils; consequently, a compromise must be effected and an oil selected which will lubricate the gears as well as possible and at the same time be thin enough to operate in the circulating system without trouble.

As mentioned before, the heavier-bodied oils made necessary by the addition of gears do not separate from moisture as quickly as lighter oil, and therefore have a greater tendency toward sludging, emulsification and decomposition. This means that greater opportunities must be provided for rest and cleaning. This can be done by using a larger oiling system or by adding settling tanks to increase the capacity, thus reducing the frequency with which the oil passes over the bearings or gears. Efficient coolers are essential, because the high temperatures of the turbine bearings will thin down the oil so that if the temperature of that going to the gears is not sufficiently low, its viscosity will be reduced to such a point that it will be of little value.

The viscosities of some of the better known turbine oils are shown in the curves. Some of these oils are very well suited to the lubrication of turbines without reduction gears, while others are more suitable for the geared types. For instance, the oil shown by curve No. 3, when cooled down to about 100 deg. F., is quite heavy and if supplied to the reduction gears at this temperature, is very satisfactory. It also has the advantage of thinning down with increased temperatures more rapidly than some of the others, and when at the temperature of the turbine bearings, between 150 and 175 deg. F., it is thin enough to prevent any extra friction in the bearings. This quality makes it easily cleaned when heated, very desirable when heavy-bodied oils are used for circulating systems.

One of the principal troubles with reduction-gear lubrication has been a tendency of the gears to pit along the pitch line. This shows up at first in the form of very small pits, which grow larger as the wear increases until a serious groove or ridge is formed. There is still some question as to just what causes this pitting and the best method of overcoming the trouble. It may be caused by surface crystallization due to vibration of the gears through an insufficiently stiff framework or slightly worn bearings, a situation that could evidently be reduced by the use of higher-viscosity oils. In a number of installations the heavier-bodied oils have stopped the trouble completely, but whether they will do so in all cases yet remains to be demonstrated.

When we attempt to write a specification for a high-grade turbine oil, we must carefully consider all these various things that influence the life of the oil and the possibility of its emulsifying or sludging in the system.

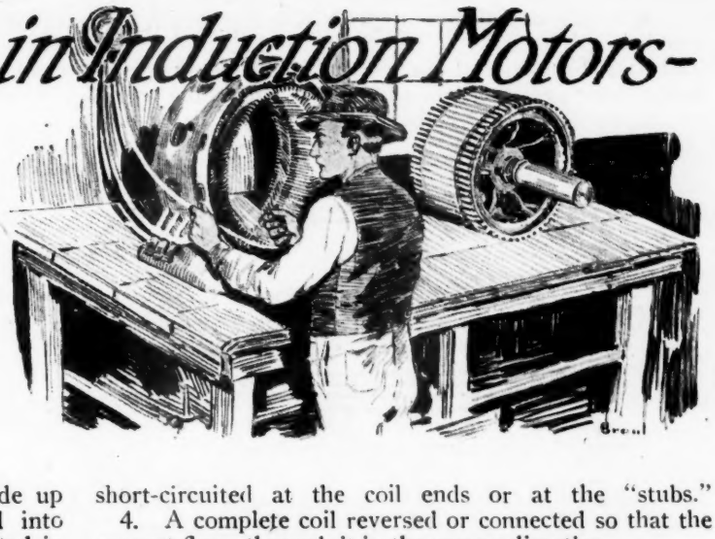
A suitable turbine oil should be a highly filtered, properly refined, pure mineral oil, free from acid or alkali, having the best possible ability to separate quickly from water without the formation of emulsions or sludging, as shown by the emulsification test. The correct viscosity is determined by the oiling system of the turbine and the temperature conditions. Standard practice has found the following viscosities, all at 100 deg. F., to give satisfaction:

Ring oiled bearings with or without water jackets	150-200 sec.
Ring oiled bearings subjected to extreme radiated heat	300-500 sec.
Circulating systems, ordinary conditions	150-200 sec.
Circulating systems, with reduction gears	250-350 sec.
Circulating systems, with reduction gears and vibration	350-750 sec.
Circulating systems, marine reduction gears	450-750 sec.

Locating Faults in Induction Motors—

Most Common Defects

By
A. M. Dudley*



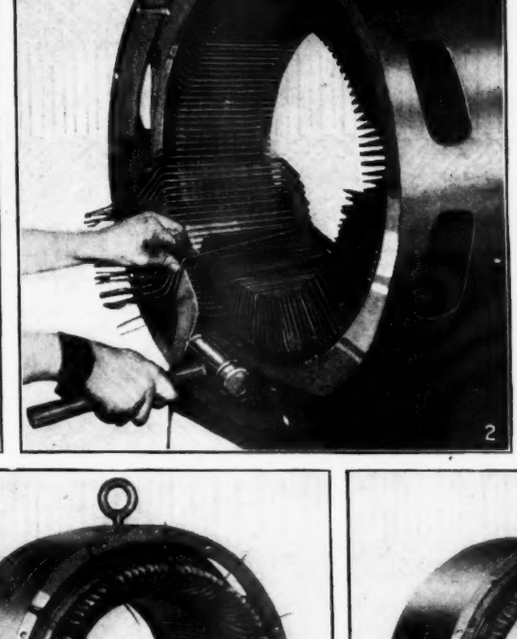
The Ten Most Common Faults in Induction-Motor Windings Are Enumerated, and the Methods Usually Followed in Locating and Correcting These Faults Are Discussed.

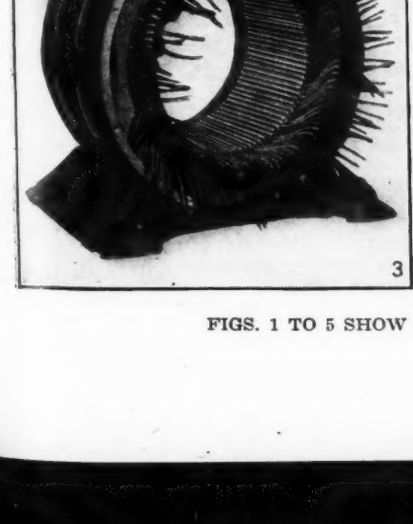
THE winding of an induction motor is made up of a number of similar coils connected into groups. These groups in turn are connected in such a manner that when an alternating current of the proper characteristics flows through them, a magnetic field having alternate north and south poles is set up and caused to rotate in the motor. The coil itself is usually made up of two or more turns of wire or strap so that there are at least ten chances for defects in the winding after the coils are all in place and connected. Some of these faults are simple and readily rectified, while others are more obscure and difficult to handle.

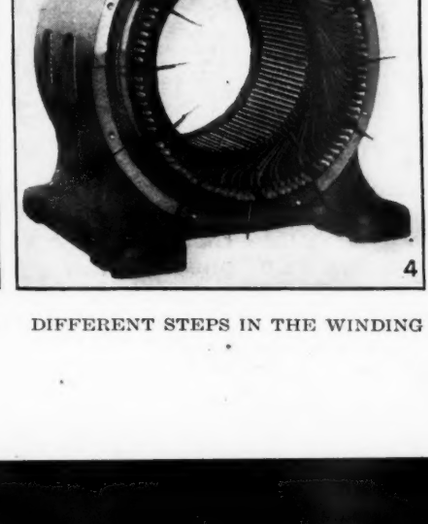
These ten most common defects in the order of their likelihood are:

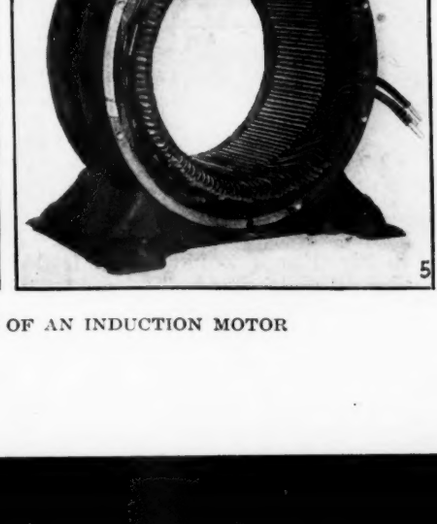
1. The winding grounded on the core.
2. One or more turns in one or more coils short-circuited.
3. One or more complete coils short-circuited at the coil ends or at the "stubs."
4. A complete coil reversed or connected so that the current flows through it in the wrong direction.
5. A complete group of coils or pole-phase group is reversed; that is, connected so that the current flows through the group in the wrong direction, making a north pole where a south should be or vice versa.
6. Owing to lack of care in counting, two or more pole-phase groups may include the wrong number of coils.
7. A complete phase in a three-phase star or delta winding is reversed.
8. The winding connections may be properly made in themselves, but not right for the voltage upon which the motor is to be operated. That is, the motor may be connected properly for 110 or 440 volts, but the motor is to operate on 220 volts.
9. The winding connections are properly made, but

*Designing engineer, Westinghouse Electric and Manufacturing Co.









FIGS. 1 TO 5 SHOW DIFFERENT STEPS IN THE WINDING OF AN INDUCTION MOTOR

they are for the wrong number of poles, and hence the motor runs at a different speed from that which was intended.

10. An open circuit somewhere in the winding, or one or more coils are omitted and left out of the winding, known as "dead" coils.

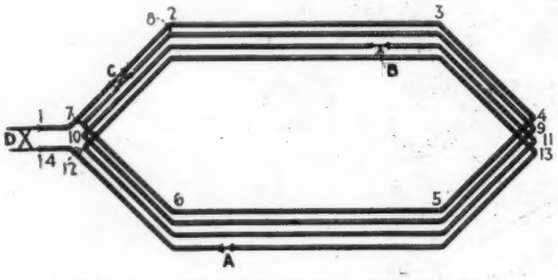


FIG. 6. COIL WITH TURNS SEPARATED

The manner in which these various faults occur can be best understood by referring to what takes place, first, in winding and insulating the coils, and, second, in placing them in the core and connecting them.

Fig. 1 shows a coil of the usual form wound up from several turns of wire and insulated ready to be used in the slot; Fig. 2, the operation of winding these coils in place in the core; and Fig. 3, the coils all in place ready for connecting. The coils connected into pole-phase groups, with the coil ends at the beginning of each group bent into the bore and the coil ends at the end of each group bent out toward the frame are shown in Fig. 4. The cross-connections are made in Fig. 5, thus completing the winding connections. Fig. 6 shows the coil in Fig. 1 as it would appear if the insulation were stripped off and individual turns of wire separated.

The first fault listed—grounding of the winding on the core—occurs when in some manner the insulation becomes stripped from the coil and also the cotton covering from the wire so that at some point, as at *A*,

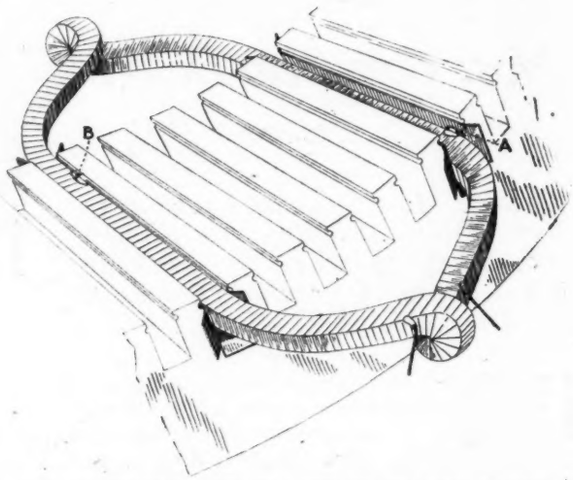
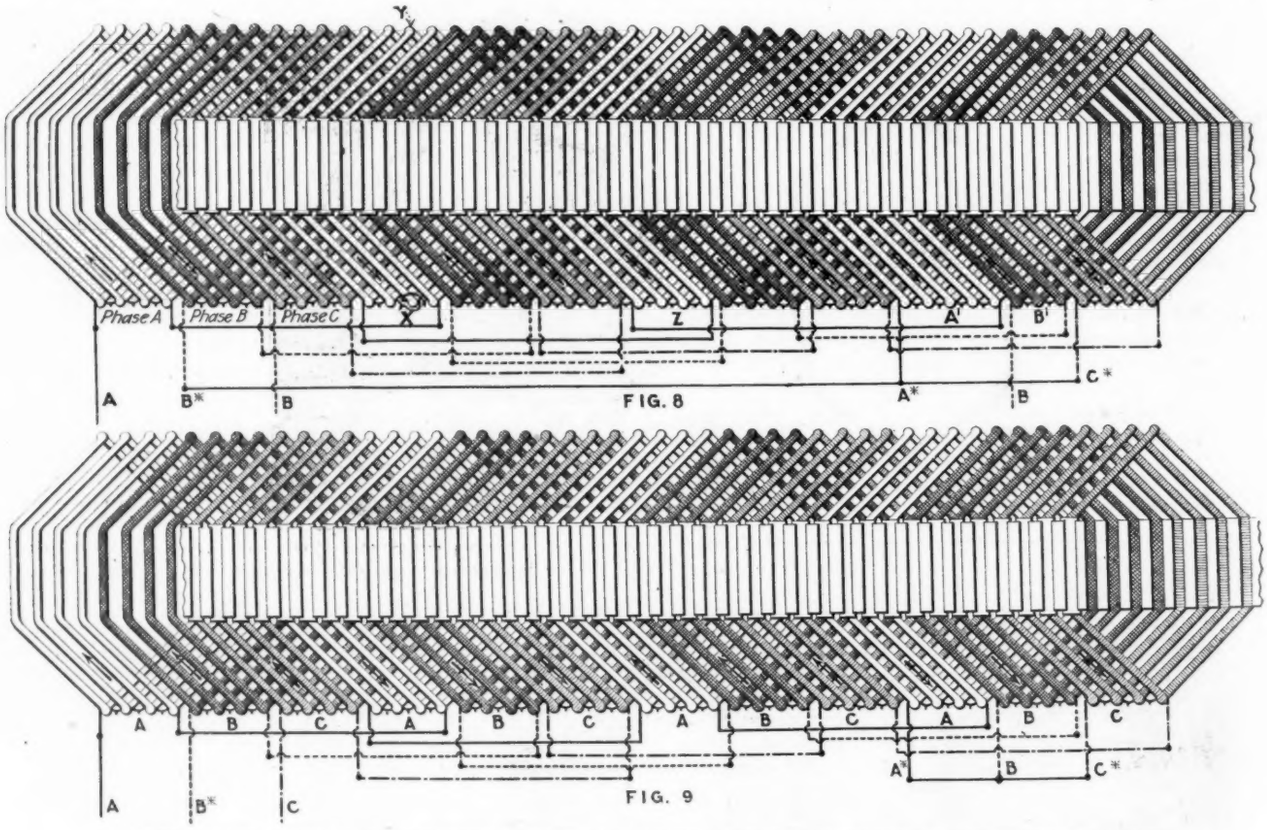


FIG. 7. SINGLE COIL PLACED IN STATOR SLOTS

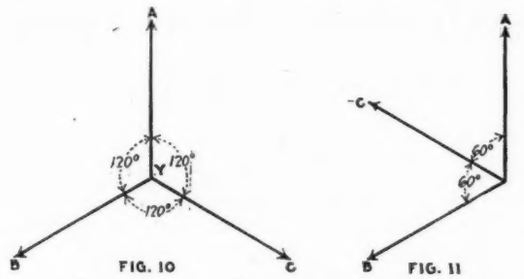
Fig. 7, the bare-copper conductor touches the laminated-iron core and by so doing "grounds" the winding. This means that a live-current carrying part is touching the metal structure of the motor, and when this condition exists anyone who touches the frame of the motor actually touches a live conductor. This may not be detected if the entire winding and the supply circuit otherwise is free from grounds, but it often happens that other grounds are present somewhere in the system so that in standing on the ground and touching



FIGS. 8 AND 9. STAR-CONNECTED INDUCTION-MOTOR WINDINGS SHOWING DIFFERENT FAULTS

the frame of the machine the chances are very good of getting a shock at a voltage that may equal that of the supply circuit.

Referring to Figs. 6 and 7, should two grounds occur simultaneously, as for example, at *A* and *B*, a short-circuit would be formed in the loop, Fig. 6, from *B* through 11, 12 and 13 to *A;* and if the normal voltage remained on the motor, this short-circuited turn would immediately become hot enough to destroy the insulation on the complete coil. This is the second fault listed and may occur without grounding by the touching of the bare conductor of adjacent turns as at *C*, where the



FIGS. 10 AND 11. VOLTAGE VECTOR DIAGRAMS

complete short-circuit follows the path of *C* 2, 3, 4, 5, 6, 7 and *C*.

The third fault—short-circuiting a complete coil—can also be seen from Fig. 6 and exists when the insulation of the ends of the coil 1 and 14 become damaged and allow these two wires to touch, as at *D*. A current then flows in the entire coil, in addition to and aside from the line current, equal to the voltage of the coil divided by its impedance. In other words, what happens is equivalent to removing that particular coil from the main winding where it is generating its share of the useful counter-electromotive force and using up this same generated or induced counter-voltage, simply, to force current through the coil itself. This coil would heat up practically as fast as would any induction motor winding if the rotor was held from rotating and full-line voltage applied to the stator winding.

The fourth fault occurs when the two leads of a coil are interchanged, as at *X*, Fig. 8. This has the effect of causing the one coil, or in this case coil *Y*, to "buck" all the other coils in the same pole-phase group. Expressing this in another way, the cross-connected coil is trying to produce a magnetic north pole when all the other coils in its group are producing a south pole. The effect of this is magnetic dissymmetry and manifests itself, as do most irregularities in winding, in noise and heating.

The fifth fault, and one that can occur readily in connecting, is when an entire pole-phase group is reversed, as at *Z*, Fig. 8. This can be understood from Fig. 4. The beginnings of all pole-phase groups are bent in toward the center of the bore, and the endings are all bent out. Should one of the ends bent out be used as a beginning and the other end as an ending, the entire group would be reversed with consequent magnetic distortion and trouble due to noise and heating.

The sixth fault is one due wholly to wrong counting in grouping the coils. In a three-phase four-pole motor with 48 coils there should be in each group $48 \div (3 \times 4) = 4$ coils, and the presence of 3 coils or 5 coils in any group constitutes the sixth fault as they are here listed. This is also shown in Fig. 8, where all the groups have 4 coils except A^1 and B^1, which have 5 and 3 coils respectively.

The seventh fault is present only in the case of three-phase motors and consists in reversing the ends of one-third of the winding so that one leg of the star or one side of the delta is connected in such a way that the voltages generated in the three phases are only 60 electrical degrees apart, whereas the currents supplied from any normal three-phase generator are 120 electrical degrees apart, and hence these three voltages and currents cannot combine to produce power as they properly should. This can be understood by referring to Figs. 10 and 11. Fig. 10 shows the three voltages generated in a three-phase winding as represented by three arrows or vectors arranged 120 deg. apart. If, however, one phase of the winding was reversed and the lead connected to the star point and vice versa, the back, or counter-electromotive, force generated in that winding would be reversed and would no longer be 120 deg. from the voltages in the other two phases, but would be 60 deg. from them, as in Fig. 11. This would mean that the magnetic field in the stator, instead of being a balanced succession of north and south poles rotating and pulling the rotor around, would become unbalanced and would no longer rotate properly. According to another method of looking at the matter, there would be one field rotating clockwise and another different kind of a field rotating counterclockwise, and the natural result would be that these two fields would interfere, and instead of rotating, the motor would remain at a standstill, emitting an unusual amount of noise and reaching a dangerous temperature in a very short time.

A four-pole three-phase winding with the *B* phase reversed is shown in Fig. 9. It will be observed that instead of the arrows on the pole-phase groups pointing in alternate opposite directions, as they should for a correct connection, they point in opposite directions in groups of three. Further consideration will be given this feature in the next article.

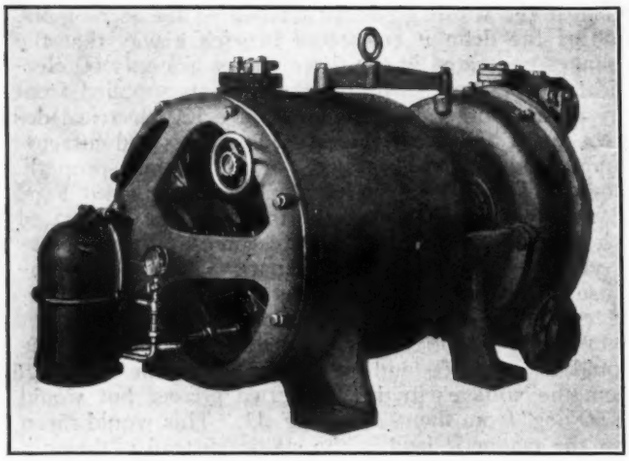
In the eighth fault the winding connections are all made properly to form the magnetic poles in their proper sequence, but there are only half as many turns in series or perhaps twice as many as there should be. When this is discovered, the winding may be such as to permit connecting in series instead of parallel or vice versa, but under the worst conditions it may be necessary to remove the entire set of coils and replace with a new set having the proper number of turns for the required voltage.

The ninth fault is sometimes overlooked unless the speed is taken with a tachometer or speed counter, in which case it is readily detected. Its correction is not always either evident or simple, but can often be accomplished without change in coils by following some one of the various methods described in the articles on "Reconnecting for Changes in Number of Poles," in *Power* for Apr. 9, 1918, Aug. 20, 1918, and Jan. 7, 1919.

The tenth fault, "open-circuits," may be due to failure to solder a joint properly or to a joint being broken mechanically after having been once made. "Dead" coils are usually purely inadvertent and are sometimes present without being discovered at all. Such an occurrence could hardly happen unless there were a large number of small coils crowded together.

(The next and last article will explain how to make the tests necessary to locate the ten faults outlined in this article.)

Henry Ford's new gasoline driven street car is nearly ready. If it is successful and Mayor Couzen's municipal ownership plan is adopted Apr. 5, the new car may become a fixture on Detroit streets. The motors are 75 and 150 hp. and will be fitted to burn alcohol in addition to gasoline or kerosene.



Steam-Turbine Governors

Shaft Governors of Small Curtis Turbines

Illustrates and describes the Curtis direct-type governor, its care and adjustments. Directions are given for putting in a new spindle and for testing the emergency stop.

CURTIS turbines from 25 and 35 kw. capacity, 3,600 r.p.m., are provided with direct, spring-tension type governors. Fig. 1 shows one of these machines connected to a generator. The governor is mounted on the end of the mainshaft and operates a double-seated balanced throttle valve through a bell crank directly connected to the valve spindle, as shown in Fig. 3, which shows the governor all the way out and the regulating or governor valve open. Weighted arms *AA* supported on knife-edges *DD* and *BB* pull outward against the spring due to centrifugal force. The governor transmits motion to the bell crank through a spindle *C*, which moves forward and backward with the spring and struts. The whole governor frame revolves, but only the spring, spindle and struts move forward and backward and these do so in a straight line. The spindle and struts are held in place by the spring and weights only. The spindle does not move in a close-fitting guide and is not lubricated. The knife-edges of the struts and weights have little movement *and must not be oiled*.

Formerly a so-called "lapseat" thrust was furnished on the outer end of the governor spindle, but this type has been discontinued and a ball thrust *E*, being more sensitive, is now used. As shown, the thrust is in the hollow end of the bell crank and has one large ball screwed on the end of the spindle. This ball is grooved for a guide, but the guide makes little or no contact in the groove as the large ball rolls on the small ones. The frictional resistance of this thrust is small, but the thrust depends on adequate lubrication to enable it to work well. The lower half of the bell crank is hollow and provided with braided yarn, oil being supplied to the yarn from an oil cup connected to the trunnion, which is provided with an oil passage. It is important that this cup be kept filled with a medium cylinder oil. If the turbine is exposed to very low temperatures, a lighter oil, as engine oil, should be used. The oil passages must, of course, be kept clear.

The Governor Valve—The valve stem is a loose fit in the governor valve to promote self-alignment. When full open, the valve is 3/8 in. off the seat and will seat tightly before the governor completes its travel. Adjustment of this difference may be made by raising or lowering the valve stem at *F*, Fig. 3. The travel of the governor spindle should be 3/8 in. and may be kept at that by adjusting shims held in the end of the mainshaft by a long screw *G*, Fig. 3.

Putting in a New Spindle—Refer to Fig. 3. To put in a new governor spindle, remove the governor casing, take out the plug *H* and unscrew the ball *E* from the spindle (right-hand thread) by using a screwdriver, the ball being slotted to receive one. Remove the bell crank, but do not remove the ball or its seats. The governor is next removed from the shaft (right-hand thread) by a special spanner furnished with the turbine. The governor is screwed on tightly, and it may be necessary to strike the spanner a rather sharp blow with a hammer to start the nut. Remove the nut *J* with the spanner; this will relieve the knife-edge seats, after which the pin *K* may be removed, the spindle taken out and a new one put in. Do not change the position of other nuts. Care must, of course, be taken not to han-

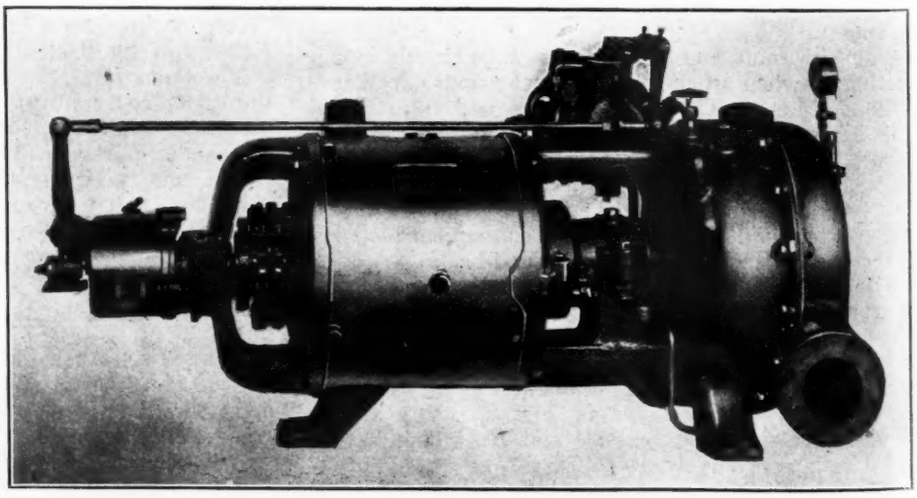


FIG. 1. SMALL GENERAL ELECTRIC TURBO-GENERATOR

dle the governor so roughly as to bend the spindle or dull the knife-edges.

The Emergency Governor—The emergency governor valve *M*, Fig. 1, is of the plain flap type, held open by a trigger. The valve and its mechanism are mounted on a separate chest, the valve fitting loosely on the resetting shaft *A*, Fig. 2. The latch holding the valve open is mounted on a tripping shaft *B*, having a lever keyed to the outer end. The square rod *C* riveted to the other end of the lever holds the tripping lever and the latch in position by being held up by a trigger *D*. A clock spring *E* revolves with the shaft, and at about 10 per cent overspeed will fly out, striking the trigger *B*, allowing the spring *F* to trip the mechanism which allows the valve to close.

Resetting the Emergency Stop—If the emergency stop trips and the turbine is to be started, close the throttle, bleed the steam from the chamber through the plugged hole *N*, Fig. 3, and raise the resetting lever as far as it will go. Always return the lever to its stop so that the emergency valve will not have to move this lever the next time it trips. If the lever is not returned to the stop, the next time the valve trips it must do so against the frictional resistance offered by the packing in the stuffing-box of the tripping shaft. The tripping-shaft bushing is not packed, and the little steam escaping is piped to the turbine casing.

It is good practice to stop frequently any turbine by tripping the emergency stop, as the packed shaft or spindles will stick from non-use and may fail to work when most needed.

When these small Curtis sets are first started, "feel" the governor by pushing in on the adjusting nut *O*, Fig. 3, the governor casings having been removed. Test the emergency stop by holding the bell crank out with a piece of cord or wire. At about 8 per cent overspeed the spring *E*, Fig. 2, should begin to fly out, and at 10 per cent should trip the trigger. If the emergency governor needs adjusting, loosen the nut holding the spring. Turn the stud so that the spring bears harder against the stop *J* if the emergency trips at too slow a speed and not so hard if it trips at too fast a speed.

When tightening the nut, be careful that the adjustment of the spring is not disturbed.

Finally, as a word of caution, do not oil the knife-edges of the speed governor, as they will collect dirt, cause poor regulation and quickly wear.

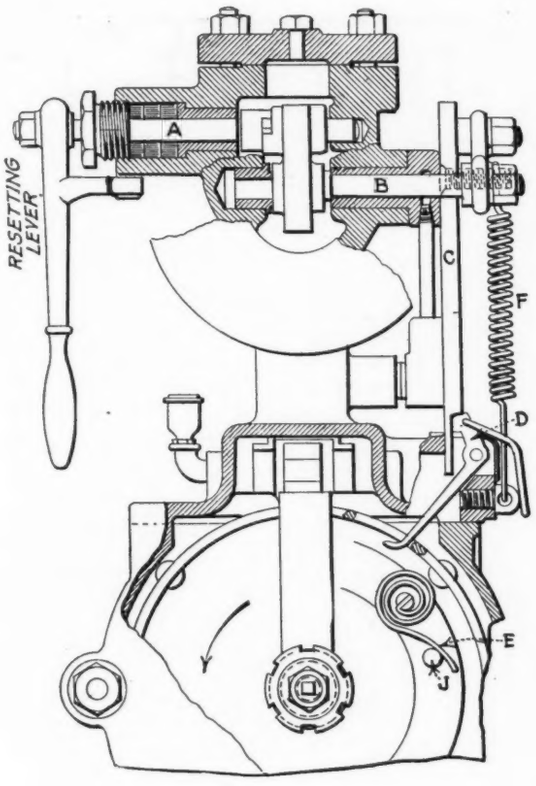


FIG. 2. EMERGENCY GOVERNOR, SMALL CURTIS TURBINES

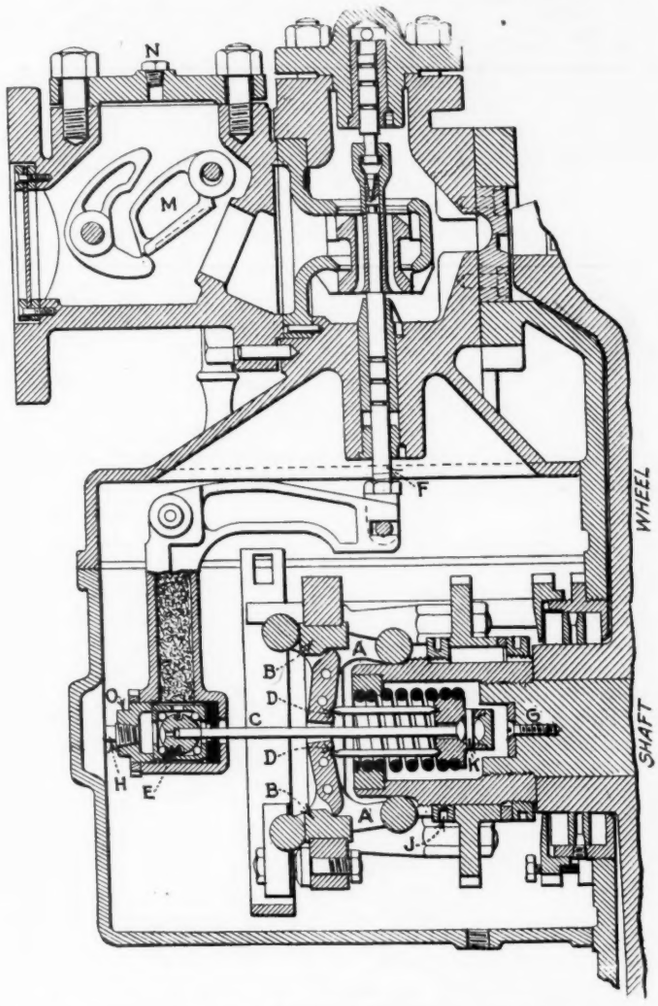
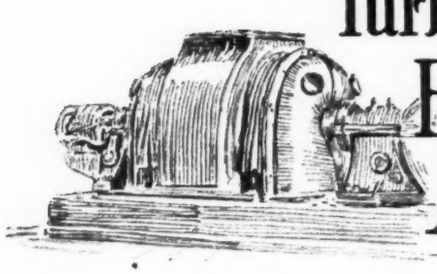
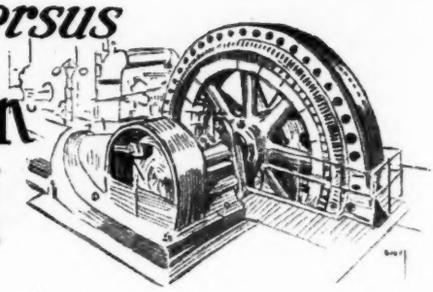


FIG. 3. SECTION OF SHAFT GOVERNOR AND GOVERNOR VALVE, SMALL CURTIS TURBINES

The application of pulverized coal to copper blast furnaces has been made successfully, according to the *Compressed Air Magazine*. This is a comparatively new application of pulverized coal to industry. The pulverized fuel is introduced into the blast pipes above the tuyeres without disturbing seriously the existing conditions at any modern blast furnace plant.



Turbine-Driven *versus* Engine-Driven Alternators-I



*By S. H. Mortensen**

A comparison of the construction and operation of the rotor of these two distinctly different types of alternator. One slow speed with a short rotor of large diameter and many poles as compared to a long rotor of small diameter and few poles built for high peripheral speeds.

OPERATING speed in revolutions per minute of an engine-type alternator is necessarily much lower than the corresponding speed of a generator driven by a steam turbine, and its number of poles for the same frequency must then be correspondingly larger. The relationship between frequency F of an alternator, its rotating speed in number of revolutions per second N and its number of poles P is,

$$F = N \times \frac{P}{2}$$

For example, an alternator rotating at 120 revolutions per minute, or 2 revolutions per second, must have 60 poles to give a 60-cycle current, whereas an alternator driven by a steam turbine at 3,600 revolutions per minute, or 60 revolutions per second, requires only two poles to develop this frequency.

This difference in the number of poles and revolutions leads to distinctly different types of machines. The extreme operating speed of the turbo-alternator imposes problems in design and operation that are unknown in engine-type machines. Comparative features of engine and steam-turbine driven alternators are indicated in the accompanying table and are shown in the sketches,

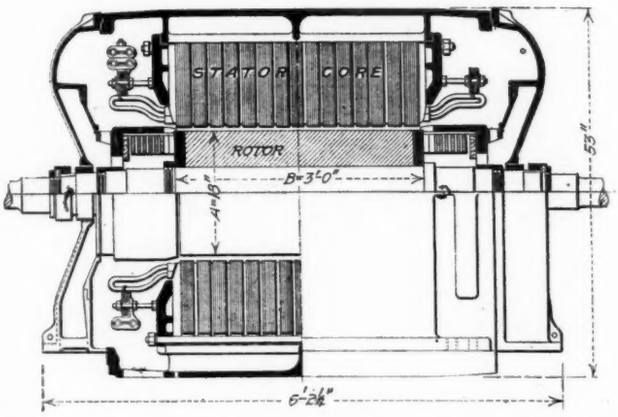


FIG. 2. SECTION THROUGH 1,000-KW. TURBINE-DRIVEN ALTERNATOR

Figs. 1 and 2, which depict the corresponding machines. Fig. 3 shows the rotor construction of a slow-speed alternator. In this type of machine the diameter has to be large enough to permit mounting the required number of poles on the rotor spider and allow the proper clearance between the adjacent coils. The axial width of the pole is determined by the cross-section required to carry the magnetic flux of the machine.

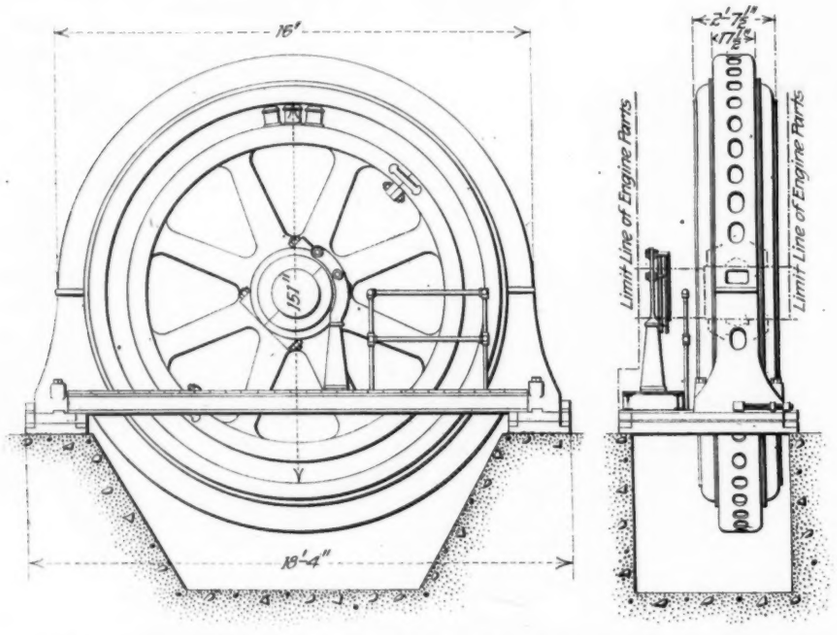


FIG. 1. CHIEF DIMENSIONS OF 1,000-KW. ENGINE-DRIVEN ALTERNATOR

As the operating speed of such machines is low, the mechanical features present no difficult problems. The pole may be held to the spider by means of bolts or dovetails, and the rotor field coils are supported between the spider and the projecting pole tips. The field coils are wound with copper strip bent on edge and insulated from each other by treated paper. Fig. 4 shows such a strap-wound coil before and after it is mounted on the polepiece. As the total outer surfaces of the field coils are exposed to the air, they are well ventilated and there is little danger of their overheating. However, the large flywheel that generally is mounted close to the alternator interferes with the ventilation and makes it necessary to place small vanes or fan blades on the spider to direct the air and insure even ventilation.

*Electrical engineer, Allis-Chalmers Manufacturing Company.

Flywheels may either be constructed as a part of the alternator spider or be mounted as a separate element on the rotor shaft. They are required to compensate for the variation in the turning effort during the revolution, inherent to reciprocating engines, and caused by the varying pressure on their pistons. The flywheel effect of the rotating parts of the alternator must then be sufficient to hold the variation in the engine speed during the revolution within certain limits fixed by the requirements of the connected machines. For alternators operating in parallel, these limits are necessarily narrow. If one rotor for any reason drops behind, power will flow from the faster to the slower machine, tending to accelerate it. If the displacement between the rotors exceeds certain values, parallel operation becomes impossible and the alternators fall out of step.

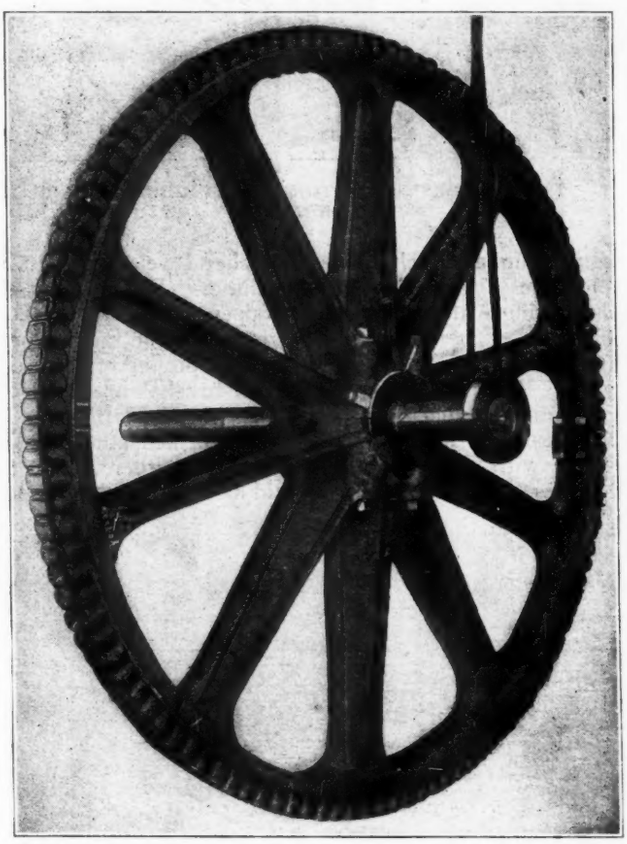


FIG. 3. ENGINE-TYPE ALTERNATOR 120-POLE ROTOR

Even with small displacements objectionable cross-currents will flow between the armatures, causing extra losses and heating in their windings. For practical purposes the flywheel must be heavy enough to limit the rotor-speed variation to 2.5 electrical degrees on each side of the position that a given point would occupy if its speed was uniform. One mechanical degree $= \frac{P}{2}$ electrical degrees, where P = the number of poles of the alternator.

For engine-driven alternators the collector rings have to be large enough in diameter to be mounted on the heavy engine shaft or on the spider hub, and generally are so liberal in size and brush capacity that they require practically no care after once they are adjusted. They are made from cast iron or bronze alloy and work with carbon brushes. The rings for the machine of Fig. 2 are shown in Fig. 8.

Turbo-alternator rotors have to meet the same requirements as the fields on engine-type machines, but in addition the mechanical stresses inherent to high-speed operation limit their diameter and lead to rotors of great axial length. Figs. 5, 6, 7 and 8 show four different stages of completion of a rotor made from a solid steel forging. Fig. 8 shows the finished rotor. To take care of mechanical stresses due to the centrifu-

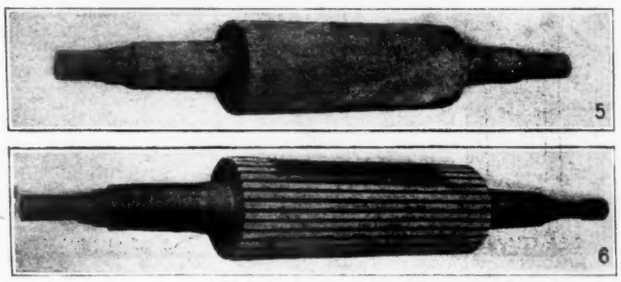
FIG. 4. STRAP-WOUND FIELD COILS FOR SLOW-SPEED ALTERNATOR

gal force, the field coils are subdivided and embedded in radial slots in the rotor. Heavy metal wedges are fitted into grooves in the rotor slots for holding the rotor coils in position. The individual turn in such a field winding is placed in the rotor slots with great care and the insulation between the turns as well as between the completed coils is generally made from micanite or asbestos, rendering the field fireproof. This class of insulation will operate continuously at temperatures reaching 150 deg. C. (302 deg. F.).

COMPARATIVE DATA ON ENGINE AND STEAM-TURBINE DRIVEN ALTERNATORS

	Turbo-Generator	Engine-Type Generator
Maximum capacity, kw. at 80% p.f.	1,000	1,000
Frequency	60	60
Revolutions per min.	3,600	120
Number of poles	2	60
Diameter of rotor over poles (A) in.	18	151
Length of rotor over poles (B) in.	36	10
Peripheral velocity, ft. per min.	16,900	4,750
Ratio A/B	0.5	15.1
Weight rotor, net, lb.	3,750	22,000
Weight stator, net, lb.	15,000	27,850
Losses due to windage and friction, kw.	20	6
Copper loss and stray loss, kw.	12	30
Excitation, kw.	11	20
Air for forced vent., cu. ft. per min.	5,500	none
Full-load efficiency	95	93.3

In the design of turbo-rotors the main problem is in the choosing of the rotor diameter together with the number and size of slots for the field coils. The diameter is to be kept as small as practicable to limit the centrifugal force and also the windage losses of the machine, but it has to be sufficient to permit the required amount of space for the field winding. For large machines the rotor velocity is limited by the strength of the material available for their construction. At the present time the peripheral velocity of



FIGS. 5 AND 6. FORGED ROTOR CORE BEFORE AND AFTER MACHINING

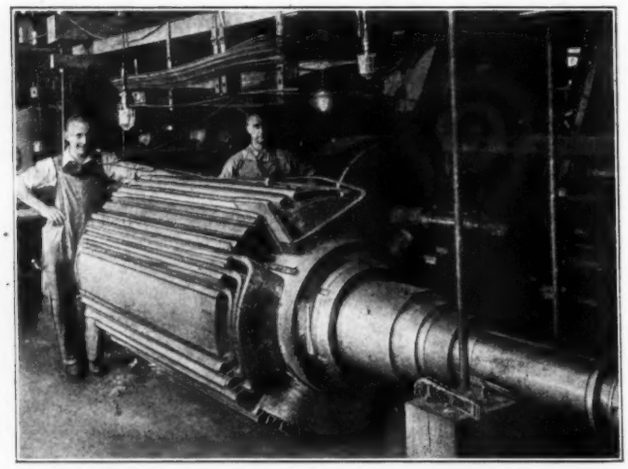


FIG. 7. TURBINE-DRIVEN ALTERNATOR'S ROTOR IN PROCESS OF WINDING

rotors is limited to approximately 25,000 ft. per minute.

The highest-stressed material is not found in the rotor body proper, but in the metal caps or rings that hold the projecting ends of the field coils in place (see *R* in Fig. 8). For large-sized machines these rings are manufactured from the strongest and toughest material available, which is alloy steel having an ultimate strength of 120,000 lb. per sq.in., or more.

Instead of being made from one forging, as shown in Fig. 5, smaller rotors may be built from punchings mounted on a shaft and clamped securely between heavy metal end plates, or from a number of steel disks either mounted upon the shaft or clamped between stub shafts. In either case the general appearance of the rotor will be as shown in Fig. 8. The choice between the solid and laminated rotors is generally decided by their tendency to vibrate, which for large high-speed machines necessitates the adoption of the most rigid construction available—the solid forged rotor. The fans shown on the ends of the rotor in Fig. 8 supply the air for ventilating the stator and rotor, and great care should be exercised in the shaping of the fan blades. Turbo-driven alternators do not need flywheels, as the turning effort of the steam turbine is uniform throughout the revolution.

On the turbo-generator the collector rings are neces-

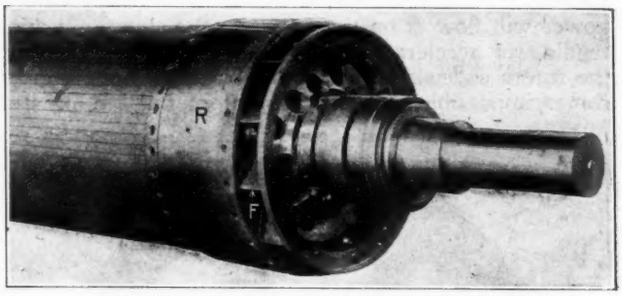


FIG. 8. FINISHED ROTOR FOR TURBINE-DRIVEN ALTERNATOR

sarily run at much higher peripheral velocity than is the case with engine-type machines. Either alloy or steel rings are used with copper gauze or carbon brushes. Care must be used to insure the correct settings of the brushes and likewise the proper brush pressure. The steel rings and carbon brushes are used on most modern machines. With the proper setting of the brushes, the rings will acquire a polished surface and work with practically no wear on either rings or brushes. However, they should be examined at regu-

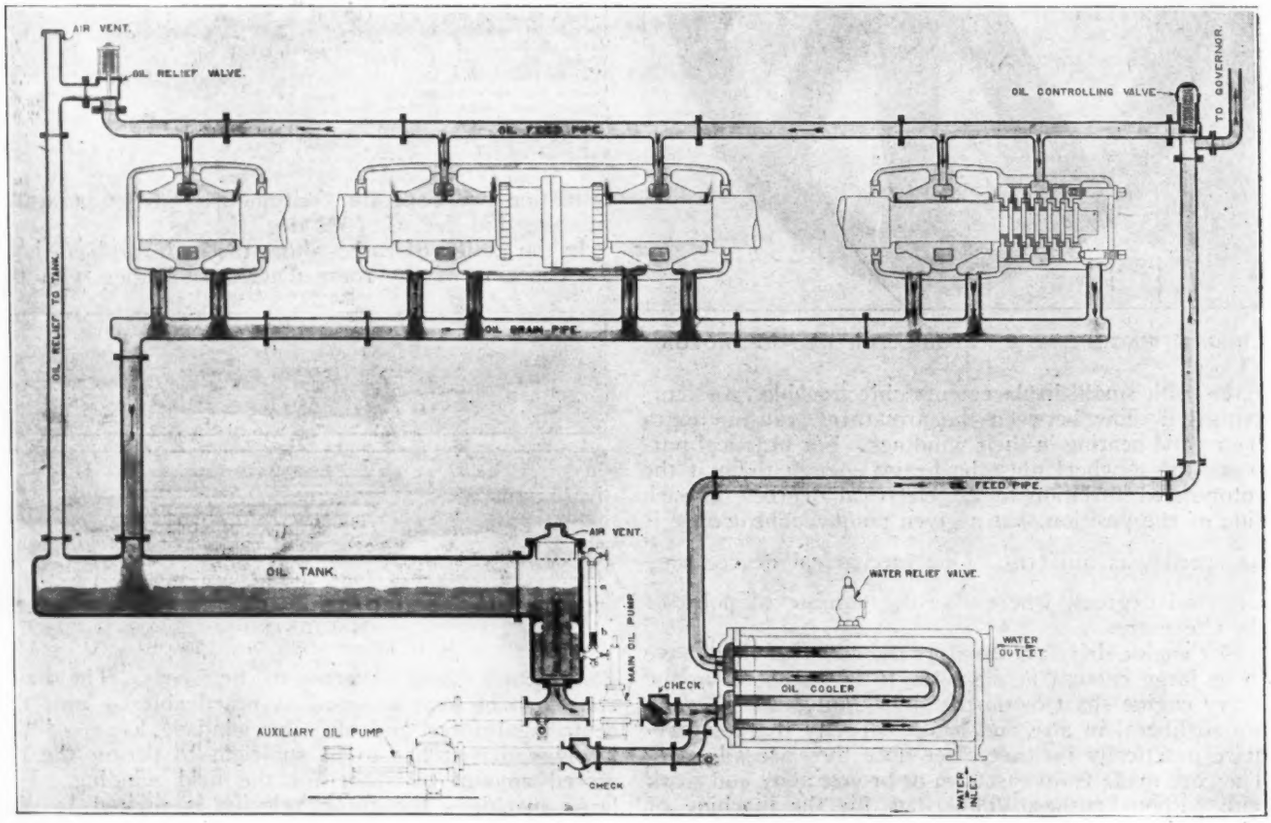


FIG. 9. LOW-PRESSURE SYSTEM OF LUBRICATION FOR TURBO-ALTERNATORS

diffusion requires time, and as the gases are being con-

the carbon will be deposited as soot or else go on up the

iar intervals, and if the surface of the rings is found to be cut or rough, it should be turned and polished at the earliest opportunity, as otherwise sparking and heating will develop and cause excessive wear on the brushes.

On engine-type alternators the bearing and lubricating system is of the well-known oil-ring type. The amount of oil in the bearings, combined with their radiating surface, makes it unnecessary to provide for any special arrangement for carrying off the heat generated by the bearing friction. With the proper inspection of this class of bearing, accidents such as wiping of the bearing lining can be eliminated, as the increase in the temperatures of the bearings inherent to abnormal operation gives ample warning for the shutting down of the machine before any damage is done.

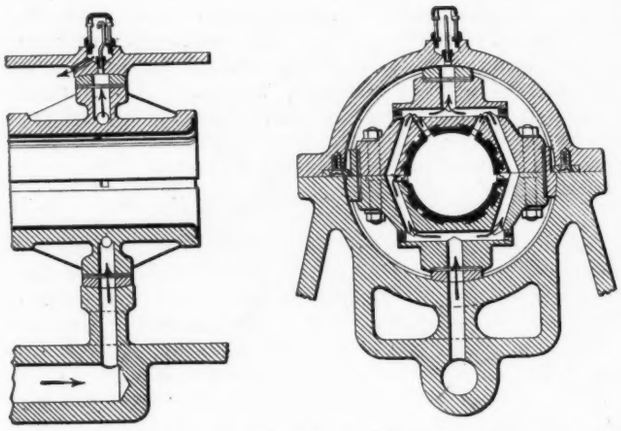


FIG. 10. SELF-ADJUSTING SPLIT BEARING OF BALL AND SOCKET PATTERN

Bearings and lubrication of the turbo-generators require careful attention in design and construction. In the design of the bearings on the early turbo-generators great ingenuity was displayed, but with the improvements in the accuracy of tools and workmanship attainable in modern shops, the self-adjusting split bearing of the ball-and-socket pattern lined with babbitt has proved itself satisfactory for this class of operation. Fig. 10 shows a bearing of this type with arrows indicating the oil flow. The lubrication of bearings is always of great importance, but especially in high-speed work, where even a momentary interruption in the oiling system invariably leads to grave results. Effective lubrication is obtained by admitting the oil to the bearings at a point of low pressure which, for horizontal turbo bearings, is on the top and sides as all the pressure on a properly erected machine is downward.

Several systems of forced oiling are in use, and in Fig. 9 one such system is shown diagrammatically. The oil is pumped from an oil tank through a strainer and an oil cooler and from there to the top and sides of the bearings. The rotation of the shaft establishes the oil film, and the heat generated by the rotation of the journals is absorbed by the continuously circulating oil carried to the cooling system and dissipated. This arrangement may be termed a low-pressure system, inasmuch as the oil pump develops only sufficient pressure to maintain an adequate flow of oil to the bearings. The system shown in Fig. 9 has, in addition to the main oil pump, a separately driven auxiliary pump for establishing oil circulation during the starting period.

Elements of Combustion of Fuel Oil

Perhaps nothing better dealing with the mechanics of combustion of fuel oil has been written than that by the United States Naval Liquid Fuel Board, whose report appeared a number of years ago. In view of the interest now taken in fuel oil in stationary plants, particularly along the Atlantic Coast, what the Board has to say about this subject is of interest.

WHILE the theory of combustion is well understood by all having a knowledge of the elementary principles of chemistry, there are particular considerations that enter into the matter of burning both oil and coal as a fuel, and therefore the economical consumption of fuel in large quantities can be effected only in boiler or furnace installations which have been designed by technically trained experts possessing a knowledge of what well may be termed the practical mechanics of combustion.

Hundreds of oil burners have been designed, which, viewed from a mechanical or theoretical standpoint, should have operated efficiently; and yet when such appliances were subjected to actual test the devices proved unsatisfactory. There are, therefore, practical conditions as well as chemical principles that must be considered in the solution of the liquid-fuel problem, and the Board thus regards the mechanical feature of the oil-fuel combustion question as a subject deserving special study and investigation.

Everyone is aware that with a charcoal or coke fire it is possible to maintain intense combustion within a comparatively small space, and with little smoke. This sort of fire was known to the smelters of the Bronze Age, and it is still used in blast furnaces and other operations where great concentration is required.

The explanation lies in the fact that the fuel is solid, even at the highest temperature. The solid particles in the smoke are probably particles of ash, but whether they are ash or unconsumed carbon, they are exceedingly small, as shown by the bright-blue color of the smoke. As a result of this solidity no carbon can leave the bed of hot coals except as a constituent of CO or CO_2. In either case the combustion will be free of soot or smoke, since both gases are colorless and transparent. If the carbon goes up the stack as a constituent of CO, it carries with it two-thirds of the heat that it is primarily capable of yielding up, and it is only with respect to the possible formation of CO instead of CO_2 that a charcoal fire fails to give perfect results. Were it not for this possibility there would be no reason why a charcoal fire should need more space than is sufficient to contain the fuel itself.

The obvious way to prevent the formation of CO_2 is to force a larger quantity of air through the bed of coal, but this alone is insufficient. Experience shows that even when the amount of oxygen passing through the bed of coal is twice that requisite for the complete combustion of carbon, there is still some of the carbon that leaves the furnace in a partly burned condition. The only way in which this carbon can be completely burned is by subsequent diffusion of the gases, whereby each molecule of CO sooner or later meets with an atom of free oxygen and so becomes CO_2. But this

From what has been said it is clear that a liquid fuel, transformers and two time-limit overload relays. As

diffusion requires time, and as the gases are being constantly cooled as they are carried along it may happen that they will be cooled below the ignition temperature before union takes place. So that even in a charcoal fire the need for appreciable combustion space is obvious.

Thorough Mixture Essential to Good Combustion

Complete combustion requires that for every atom of carbon, and for every two atoms of hydrogen, there shall be at least one atom of oxygen brought in close proximity, and then and there subjected to a temperature sufficient for ignition. In other words, there must be a thorough mixture, and then ignition. It is doubtful if a mere mechanical mixture, however complete, could ever be perfect enough to bring about the desired result. This is well illustrated by contrasting the smoky combustion of black gunpowder, where there is a mechanical mixture, with the combustion of the so-called smokeless powders in which the mixture is so thorough and minute that similar proportions of oxygen, carbon and hydrogen occur in each separate molecule.

In all ordinary cases of combustion, however, where we draw our supply of oxygen from the atmosphere, it is only by virtue of the property of diffusion that a sufficiently intimate mixture is attained. As to the real nature of diffusion, it is known that at ordinary temperatures the particles of oxygen in the air are moving in every conceivable direction with velocities averaging over 1600 ft. per sec. Any one atom, however, moves only an inappreciable distance before being arrested by collision with another atom, so that although the average velocity of the atoms is probably equal to that of a rifle ball, it still takes an appreciable time for a particle to travel even a moderate distance. It is this time element that constitutes the great stumbling block when the attempt is made to burn a large amount of combustible in a small space.

Combustion of Hydro-Carbons

As before noted, the reason why intense combustion is easily attained with a charcoal fire is that the fuel is solid at the temperature of ignition. Being solid it can present a large surface for the oxygen to act upon, and an atom cannot break away and go up the chimney first without being united with at least one atom of oxygen. In the combustion of hydro-carbons, on the other hand, we have the following condition: The fuel is already on its way to the chimney before it is even partly burned. The first effect of the heat is to dissociate the carbon from the hydrogen. Whether or not the latter unites with the oxygen does not affect the soot or smoke question, since the constituents, and also the products of combustion of hydrogen, are like transparent colorless gases. But in any case the carbon left alone in the form of an impalpable dust is much less favorably circumstanced than that in a charcoal fire. If it were attached to a hot coal, as in the charcoal fire, so as to be capable of receiving a blast of air, its combustion would be easily accomplished. But instead of this it is carried along by the current of gases, and unless it is given plenty of time before being cooled it will be left alone as a particle of soot.

An examination of the nature of flaming leads to similar conclusions. The luminous part of a flame is caused by the white-hot particles of carbon. These particles have been robbed of the hydrogen with which they were formerly associated, and they have not yet met the oxygen necessary for complete combustion. This process of finding, or of being found by, the oxygen requires time, and if perchance the temperature falls below that of ignition before the process is completed, the carbon will be deposited as soot or else go on up the stack as smoke along with the excess oxygen, with which it should have been united. Thus an unmistakable symbol of the conditions that are necessary to burn a large amount of combustible in a small space is a short flame. The circumstances which conduce to shortness of flame are: First, pure carbon fuel, because the fuel cannot leave the grate or furnace until it is burned to CO at least. In any case it cannot deposit soot, since CO, when cooled, is a transparent gas. Second, intimate initial mixture of oxygen with the fuel, since the more intimate the mechanical mixture the less time will it take the gases, by the process of diffusion, to become perfectly mixed. Third, initial heating of the air, since the rate of diffusion increases with temperature. Fourth, large surface of fuel presented for impact of the oxygen.

Proper Size of Combustion Space

The desirability of supplying a combustion chamber whose volume is at least equal to the volume of the flame seems obvious. In this connection the fact should not be overlooked that a slight increase in the volume of the combustion space acts two ways to improve the solidity of combustion. One way—that having to do with the greater time permitted for diffusion—has already been touched upon; but apart from that there are influences that work, in consequence of which an increase in the volume of the combustion space actually diminishes the volume of the flame. This is because the temperature of the larger space is higher, and the higher temperature hastens the process of diffusion.

During the process of diffusion heat is being liberated at all points throughout the combustion space. Therefore, all parts of the space are being traversed by heat rays emanating from every other part of the combustion chamber. It is readily seen that the temperature within the space must under these conditions increase with the volume to an extent limited only by the transparency to radiant heat, and by the temperature of dissociation at which necessarily heat ceases to be liberated. Since the transparency of the combustion space is diminished by the presence of solid carbon (for whether black or incandescent, it is in any case opaque), it follows that the increase of temperature with a given increase of volume will be less in a space filled with luminous flame than in one filled with burning hydrogen or CO.

Incandescent Walls Hasten Diffusion

The question of the proper size of the combustion space is further complicated by the presence and condition of the solid walls of the furnace; whether, for instance, they are themselves incandescent, or merely black absorbers of heat. There seems no reasonable doubt, however, that incandescent walls will hasten diffusion and hence shorten flame.

Where it is possible for the diffusion to be completed before combustion begins as in the bunsen gas burner, the difficulties naturally disappear, and there is readily attained a very short flame, which, moreover, is incapable of depositing soot, even on a cold body.

In the case of liquid fuel, which is incapable of vaporization, the diffusion and ignition must occur simultaneously. With such a fuel there is bound to be considerable flaming. Another difficulty, and one from which all solid fuels are free, arises from this sort of fuel from the action of capillary or surface tension. Thus no matter how finely the liquid is pulverized, each tiny drop assumes a spherical shape and so presents the least possible surface for the impact of oxygen atoms.

From what has been said it is clear that a liquid fuel, such as crude petroleum, requires an ample combustion space—more, indeed, than does almost any other sort of combustible material.

The relative dimensions, like breadth and depth, of the combustion space are of minor importance. A primary requisite is volume, and that alone provided all parts of it are traversed by the same quantity of gas in a given time—in other words, provided the gases are not short-circuited through or across some parts of the space to the neglect of others. The advantages are in favor of the combustion space of large cross-section and short in the direction of the flow of the gases.

A primary requisite for the successful burning of a nonvolatile liquid fuel is the exposure of the fuel to the heat of the furnace in such a form that it presents the largest possible surface for the impact of the atoms of oxygen. From the principles of capillary action it is possible to establish a standard by which to judge of the efficiency of the various methods of increasing the free surfaces of the oil.

Oil in bulk has practically no surface. When broken up into fine drops, the surface is the aggregate surface of all of the drops. The smaller the drops the more perfect the spheres. Hence, drops of oil one-thousandth of an inch in diameter are known to assume the spherical form with a rigidity comparable to that of a steel ball one inch in diameter. The work necessarily performed by the atomizing agent is simply the work of stretching the surface.

Automatic Compensator for Starting Induction Motors

A compensator for automatically starting and stopping squirrel-cage type induction motors or for controlling them from remote points has recently been developed and placed on the market by the Industrial Controller Co., Milwaukee, Wis. The entire starting and stopping is accomplished by means of remote-control stations, one or more of which can be situated at convenient locations, while the compensator can be placed near the motor. A float switch or pressure regulator may also be used to operate the compensator. The compensator, shown with the cover removed in Fig. 1, consists of two oil-break magnetic contactors, two auto-transformers and two time-limit overload relays. As indicated in the figure, the switch mechanism which is immersed in oil occupies the upper portion of the casing. Each of the contacts is closed by the electro-magnets *M* and *M*, one connecting the motor to the line through the auto-transformers, and after a predetermined period the other magnet connects the motor directly across the line.

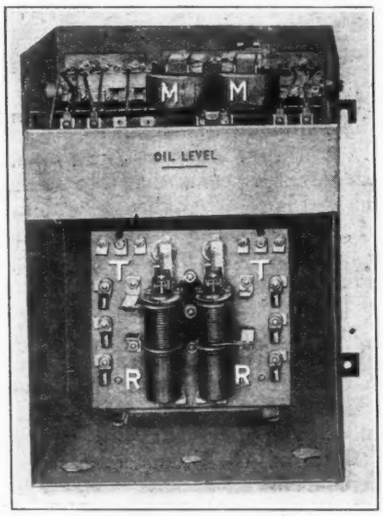


FIG. 1. AUTOMATIC COMPENSATOR WITH COVER REMOVED

The control stations, Fig. 2, are provided with a starting handle *H*, which is depressed for starting, and a stop button *S*, provided with a lock-out mechanism so that the control station may be locked open, and the motor cannot be started until the stop button is released. If desired, these stations can be equipped with an inching button, which is used only for this purpose. A simple adjustment is provided within the control stations so that the starting-time interval can be changed to suit each individual application, without going near the compensator. At starting, the operator presses down the starting levers on the control station, which automatically throws in the contactor connecting the auto-transformers into circuit. After the proper time interval a positive-geared clock mechanism in the control station, similar to that in an automatic messenger-call box, energizes the coil that closes the contactor connecting the motor directly to the line. It is impossible to have both contactors closed at the same time, since they are mechanically interlocked.

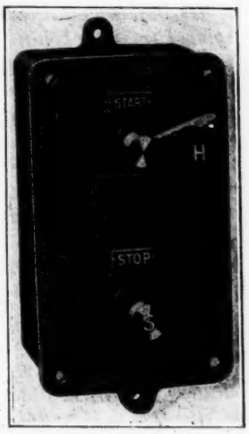


FIG. 2. CONTROL STATION

Overload protection is provided by two time-limit overload relays *R* and *R*. Current adjustment of the relays is accomplished by turning a thumbnut at the top of the relays, and time adjustment is made by changing the size of the valve opening in the dashpot plunger. Proper starting voltage is obtained at the motor's terminals by taps brought out to terminals *T* and *T* on the panel board. To make the voltage adjustment, all that is necessary is to change the transformer taps from one terminal to another. Since the compensator can be locked closed and the controller stations locked in the off-position, this piece of equipment is strictly a safety-first device.

England Adopts American Industrial Policies

The average generating capacity of the 600 establishments in England that sell electric current is only 5,000 hp. each. This is about one-fourth the capacity of a generating plant of economical size. So unorganized is the whole electrical industry that "one cannot purchase a simple electric bulb without specifying the particular type of socket" in which it is to be used. There is a strong movement in England today to divide the entire country into sixteen power zones, under the control of the government, and gradually to replace existing plants by sixteen superpower stations, capable of supplying industrial power to the whole of England. This movement is the outgrowth of the conviction on the part of many officials that the electrical industry is the "key industry" upon which depends Great Britain's future position in the trade of the world.

Pulverized Coal Under Central-Station Boilers

By JOHN ANDERSON*

Equipment Required, Method of Applying and Facts Concerning Operation. The Chief Merits of Powdered Coal Are High Efficiency and Flexibility To Meet Varying Demands

On Feb. 19 and 20 the Oneida Street plant of the Milwaukee Electric Railway and Light Co., with five of its boilers equipped for burning pulverized coal, was open for inspection for the first time to visitors who had previously registered for the occasion. Invitations had been sent out by the Technical League of the Employees' Mutual Benefit Association. Under the auspices of this company organization a most interesting paper was delivered Thursday evening by John Anderson. There was an introductory on the use of pulverized coal (reproduced in the article following), a complete report and analysis of a four-day test on the five boilers in the plant under average operating conditions, in which comparisons were made with underfeed stoker operation, followed by comments on the feasibility of burning pulverized fuel in the power plant by Paul W. Thompson, Technical Engineer of Power Plants, Detroit Edison Co., who had been an observer of the test. His opinion and the report of the test are given on other pages of this issue.—Editor.

UP TO within a few years ago, the use of powdered coal was most advantageous in those furnaces that operate under a slight pressure for the purpose of excluding air when the doors are opened and wherein a low velocity of gas travel is desired—typical requirements of furnaces in the cement, copper and iron industries. For these special and for similar reasons, pulverized fuel found its greatest use in annealing and forging furnaces; in puddling open-hearth steel and smelting furnaces; in cement and lime kilns; in the manufacture of refractories and substances that require drying or burning; and in surface treatment of many metals.

However, with the recent heavy increases in price of coal any process which promised greater efficiency found a broad field opened up before it for application to stationary boilers. Previous to this time some work had been done in developing its use in locomotives, but the reasons for its application to stationary-boiler furnaces, and the small saving that might be effected with coal at a low price, did not promise to offset the cost of pulverization. Such conditions did not encourage the use of fuel in powdered form, therfore, until the higher prices of the last three years forced economy in every direction.

In any industry the use of pulverized fuel necessitates a special plant for preparing the coal. It is the cost of installing and operating this plant that will always determine the advisability of adopting powdered coal for steam generation in any one location. In such a plant there must be equipment to separate trampiron from the coal, to crush it to a size suitable for drying and feeding it to the pulverizers, to remove the moisture, and then to grind it to the desired fineness.

As the coal is received at the plant in the form it left the mines, it is necessary to pass it over a magnetic separator which removes all trampiron, such as bolts, nuts, pick-points, etc., this serving as a safeguard against damage to the pulverizing and conveying machinery. A crusher must be used to reduce the green coal to a size suitable for proper drying and pulverizing, unless coal can be procured in sizes less than ½-in. screening without sacrificing heat value which is usually at its lowest in smallest size screenings.

The fuel is next dried, the object being to bring it to a condition in which it can most easily be pulverized and most uniformly controlled by feeders into furnaces. In a pulverized-coal fired furnace uniform temperature conditions are obtained with dry coal. Moisture in varying or large quantities in pulverized fuel definitely prevents a regular controllable flow of mixed fuel and air to the burners. For the removal of moisture a mechanical drier, which reduces the water content of the fuel to about one or two per cent, is installed. This drier usually consists of a double rotating cylinder, so arranged that hot gases from a small furnace are passed through the coal as it travels by gravity through the shell of the drier and is delivered to the pulverizers.

The dried coal is next fed into the pulverizers. The fuel is ground to an impalpable powder, varying in fineness from 80 to 85 per cent, through a 200-mesh screen. This process completes the preparation cycle, and the coal in this form, after being conveyed to storage bunkers adjacent to furnaces, is ready for firing.

Dust collecting and reclaiming equipment, although only auxiliary to the drying and pulverizing machinery, is of great importance in the economical and clean operation of a preparation plant.

In preparing coal the cost per ton depends upon the size of the plant and the quantity of fuel handled, but ordinarily will vary between the limits of twenty-five and fifty cents. It seems that a great deal of work toward reducing this cost remains to be done, especially along lines of utilizing waste gases for drying, in plants not provided with economizers. Development of a furnace design that will allow of burning a large percentage of finely divided coal, but capable of taking care of a smaller amount of larger-sized particles, presents an opportunity for further study along this line. This is possible in view of the fact that the pulverizers consume about 86 per cent of the total electric energy required for all moving parts of the coal preparation equipment. Both of the items mentioned above, if capable of being reduced as suggested, will also cause a reduction in the cost of the pulverizing-department labor.

Continuous and uniform operation of the pulverizing division of a plant is dependent largely upon the ability of the operators to recognize and meet the varying properties of the coal as it arrives. Drier operation especially must be changed frequently so as to handle varying sizes of coal (from high percentages of dust to high percentages of small nut) and varying amounts of moisture, both inherent and surface, and yet supply continuously a coal of uniformly low moisture. Irregularities in the drying process usually manifest themselves throughout the entire coal cycle, and very often with the result that the fuel-feeding system becomes plugged at points most readily affected by wet coal.

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Little need be said concerning the equipment which feeds the fuel to the furnaces. Feeder screws driven by variable-speed motors carry the fuel from the storage bins to the air-mixing chambers from which it is blown as a mixture through pipes to the burners and then into the furnaces. The feeder-motor controls at the Oneida Street plant are all provided with cutouts, and if at any time the air blast to the mixing chambers and burners is lost due to a blower shutdown, all coal feeders are automatically stopped, thereby preventing serious plugging with attendant interruption to the operation of the boilers for what could easily be a considerable period. Air additional to that used for carrying the fuel into the furnace is taken through auxiliary inlets located in the furnace front and can be varied in amount by manipulation of the stack damper, which serves to change the gas velocities through the boiler and thus

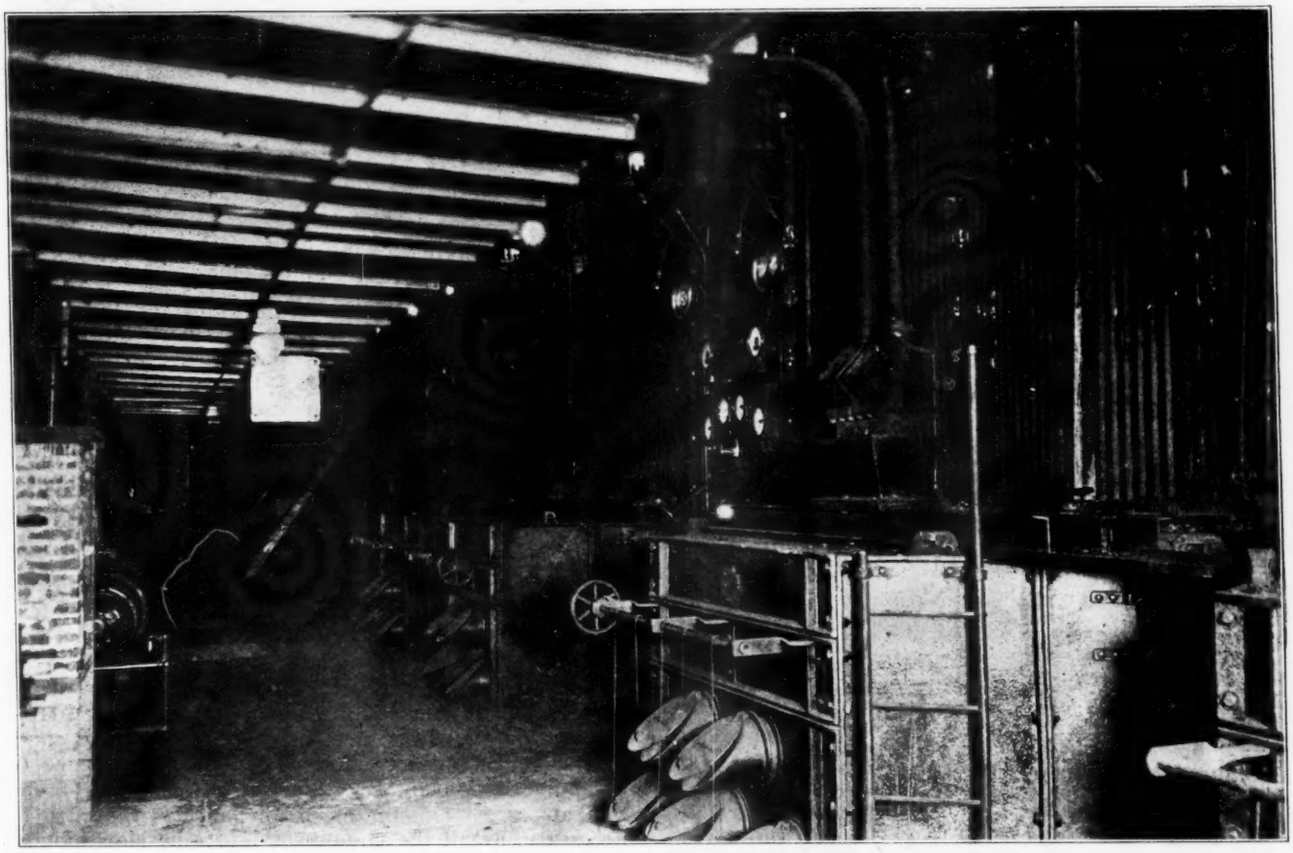


FIG. 1. PULVERIZED FUEL FURNACES AT ONEIDA STREET STATION

the volume taken into the furnace. With coal and air supplies easily adjustable, perfect fire control is assured and it becomes at once obvious why coal is burned so efficiently in pulverized form.

In further explanation of this it is well to consider briefly the indications of efficient combustion applied to the steam boiler. Chief among these is the percentage of carbon dioxide, or CO_2—the product of complete combustion—which is found in flue gases. Next in importance is the percentage of carbon monoxide, CO—a product of incomplete combustion—which may be found at the same time.

The condition desirable is that with the percentage of CO_2 as high as practicable there should be no CO—a condition obtainable to a greater degree in a pulverized-fuel furnace than in any other type. Complete combustion with the least amount of excess air requires the best distribution of that air and the problem of furnace efficiency therefore resolves itself mainly into one of air supply, not to the furnace alone, but to each particle of coal. With a fuel finely pulverized, air can be made at once available to each particle, since the surface exposed to the air is increased many times that of a lump and combustion is rapid, complete and efficient. With fuel in lump form air must be supplied through a bed, the outer surface of the lumps must be burned off, the process of combustion eating into the lumps slowly, and as a result combustion is often gradual and unequal. Where the fire is thin, too much air is passed; where it is heavy, there is too little air. To insure complete combustion in any furnace some excess air must therefore be provided. The use of pulverized fuel reduces this excess to a minimum, gives a higher and more uniform percentage of CO_2 and therefore also a higher and a more uniform efficiency.

In pulverized-fuel practice the percentage of CO_2 to be maintained is determined to a great degree by furnace limitations rather than combustion consideration. From 16 to 17 per cent CO_2 in the flue gases is easily obtainable, but it cannot be maintained in actual operation due to exceedingly high flame temperatures that result in the consequent destruction of the brickwork. The temperature of the furnace therefore must be regulated by varying the volume of excess air. The temperature of the flame should not be above 3,000 deg. F. and that of the brickwork in the flame zone not more than 2,400 or 2,500 deg. F. Higher temperatures than these usually result in fusion of the ash particles and formation of a molten slag that is very destructive to the brickwork with which it comes in contact.

In attempting to carry combustion conditions of a furnace so as to obtain exceedingly high percentages

of CO_2, usually too little attention is given to the losses resulting from the formation of carbon monoxide or CO. Carbon monoxide, a highly combustible gas, is formed when the excess air admitted to the furnace is insufficient to properly surround and completely oxidize all the coal particles. Heat losses occurring when carbon monoxide is present in the gases of combustion outweigh any gains that may be effected by an exceedingly high CO_2 and are always to be avoided.

In the discussion of furnace efficiencies consideration should be given to the adaptability of a pulverized-fuel fired furnace to the use of widely varying grades of coal without resultant losses in economy. Further, boiler capacity, even under heavy overloads, is in no way affected when an inferior quality of coal is burned. It is known that the combined efficiency of a boiler and furnace does not decrease when the fuel is poor, which condition does not hold true for the stoker. In the case of the stoker, the dropping off in efficiency is at a more rapid rate than the B.t.u. value of the fuel would indicate as normal, and so much so that the point is rapidly reached when proper combustion cannot be maintained.

Operation of a pulverized-fuel fired boiler equipped with proper instruments can be varied to take big fluctuations in load over very brief periods of time. A heavy overload can be quickly taken on or dropped off by adjustment of the coal and air feeds, and without any waste of fuel as always occurs under like conditions in stoker practice. No losses occur due to clinkering of coal or cleaning of fires, this condition of operation being entirely eliminated. Irregularities caused by change in quality and variation in size of coal, such as the fireman cannot successfully cope with on stokers, are also eliminated. Furnace conditions necessary to most economical combustion are more perfectly ob-

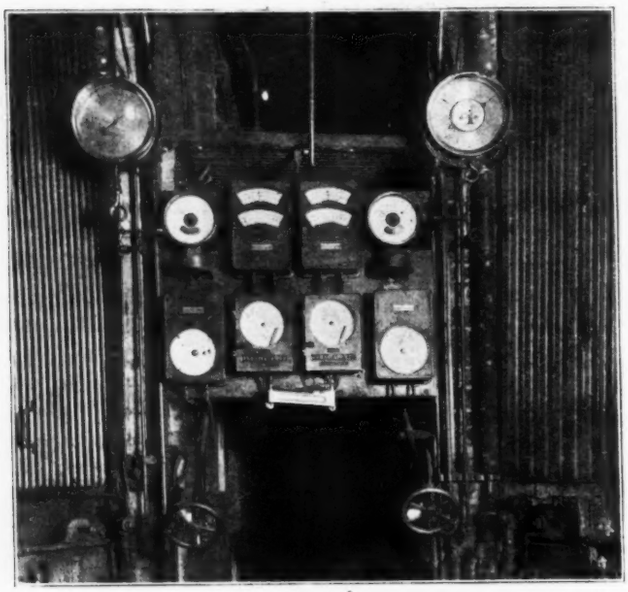


FIG. 2. INSTRUMENT BOARD FOR TWO BOILERS

tained and hence a horizontal combined efficiency curve is possible of approximate attainment.

Due to its easily regulated coal and air supply and its perfectly controlled rate of combustion, the pulverized-fuel furnace practically eliminates losses of combustible in ash. Ordinarily, this loss is relatively large and varies according to the nature of the coal, type of stoker and the boiler load carried. In pulverized-fuel practice the loss is very small and these variations do not occur.

The ease with which the fuel feed and draft is controlled, the ability to take on and drop off heavy overloads in a brief time, the thorough combustion of the coal and the uniformly high efficiency obtainable under normal operation constitute the chief advantages of pulverized fuel over other methods of coal burning.

An additional economy is effected during banked boiler hours. Banking conditions when operating with pulverized fuel are somewhat different from those ob-

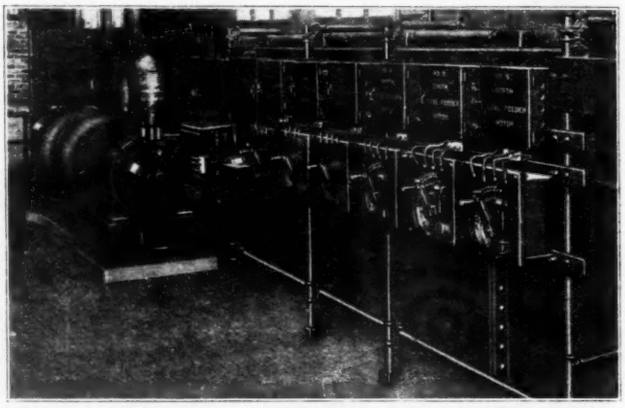


FIG. 3. BLOWER UNIT AND FEEDER CONTROLS

tained in stoker practice. By stopping the fuel supply and closing up all dampers and auxiliary air inlets, a boiler fitted for use of pulverized fuel can be held up to pressure for several hours. The furnace brickwork, having been heated to incandescence during operation, gives off a radiant heat which is almost all absorbed by the boiler rather than escaping up the stack intermixed with an excess of cooling air. Only radiation losses occur, as against radiation plus stack and grate losses in the case of the stoker.

Commenting for a moment on the maintenance features of such a plant as has been described, it is the writer's belief, based on two years' operating experience, that the furnace brickwork in a pulverized-fuel furnace will stand up equally as well as a stoker installation, with a very great advantage in favor of the former due to the elimination of all ironwork in the furnace or anywhere near the high-temperature zones of the boiler furnace. Regarding the maintenance of the pulverizing-plant equipment it has not been found that any great amount of maintenance is likely to be necessary, as all the equipment is of the slow-moving type and many opportunities are afforded of applying the same concentration of effort that has been typical of the stationary engineer's work in improving equipment when defects or fast-wearing parts are uncovered. The pulverized-machinery manufacturers have done a great deal along this line, but there are still matters that can be improved upon by the engineer looking for the least troublesome as well as the most economical plant from a maintenance standpoint.

Powdered-fuel installations are not feasible in every location. There is one limitation and that is the size of boiler plant to be served. A plant of less than 2,500 developed boiler horsepower on a 24-hour operating basis should not consider using powdered fuel. The amount of coal pulverized per day, the cost of installation, and the labor for operating the preparation plant, when properly studied, will bring before those interested the reasons therefor.

In general, we have found the powdered-fuel method applied to our furnaces a distinctly advantageous one. Our firemen prefer to operate such equipment rather than the stokers when it becomes a matter of choice.

It has proved more economical, as evidenced by the monthly coal bill. It seems to make the formation of scale in the boiler less than in stoker-fired boilers. There is absolutely no trouble from smoke, consequently no reduction in ability of the boiler to absorb heat due to soot on the tubes.

The use of high-sulphur coal, which is so destructive to boiler tubes, breechings, smokestack and all other steel equipment found in a boiler plant, is much more satisfactory as the low moisture content of the coal as fired reduces the opportunity for attack from sulphuric acid.

Although frequently cautioned against explosions, we have had no evidence that such caution is necessary. The reason for our freedom from such unpleasant occurrences is due almost entirely to a proper care in preventing coal from being dried too much and pulverized to a fineness beyond what is necessary. Matters of a kind similar to the foregoing are in the hands of the operating engineers and do not benefit by the high-brow application of theories. The engineer who is careful of his everyday equipment and keeps his plant free from accidents of every nature, from flywheel explosions to burned-out motors, can operate a pulverized-fuel plant successfully without other assistance than his own experience, as with the exception of the drier, the manipulation of the plant is simple.

An actual comparison of results obtained with pulverized fuel and with a stoker-fired furnace has been derived from tests conducted on both at the Oneida Street plant. [These tests are presented on other pages of this issue.]

Pulverized Fuel at Oneida Street Plant*

By PAUL W. THOMPSON

Technical Engineer of Power Plants, Detroit Edison Company

THERE is at the present time a considerable difference in opinion among engineers as to the feasibility of burning pulverized coal in central generating stations, and as to whether, taking all facts into consideration, the use of pulverized fuel will result in a net saving over the results obtained with modern stoker installations. It is to be presumed that a general comparison of any two plants, one equipped with stokers and one equipped for the preparation and burning of pulverized fuel, would probably not give results which could be readily comparable in determining the ultimate relative value of one method of burning fuel over the other because of the probable different conditions of operation and the difference in design, kind and cost of fuel, cost of labor, etc.

In order to determine the feasibility of burning pulverized fuel, the Milwaukee Electric Railway and Light Co., early in 1918, decided upon a trial installation on one of the 468-hp. boilers in the Oneida Street power plant.[1] The necessary equipment was installed and after preliminary operation and making certain changes which were found to be necessary, they found that the installation had proved to be entirely successful, so the remaining four boilers in the south end of the plant were equipped for burning pulverized fuel. By so doing they now have five 468-hp. boilers under which the pulverized-fuel system has been installed. This is practically one-half the boiler capacity of the Oneida Street plant and is a sufficiently large installation to compare directly with the other boilers in this station having Riley underfeed stokers, or similar boilers in the Commerce Street station also equipped with Riley stokers, which are subjected to practically the same operating conditions as are the boilers under which the pulverized fuel is burned.

To obtain data on the pulverized-fuel equipment for the purpose of comparing it with their stoker installation and determining the relative advantages, the Milwaukee Electric Railway and Light Co. conducted tests, presented elsewhere in this issue, at which the writer was present as an observer. The five boilers were operated at as nearly a constant rating as possible of 120 per cent for a period of four days from Nov. 11 to 15. Throughout the duration of the test data were taken from which the over-all efficiency of boilers and furnaces was computed and also attention was paid to the operating labor cost. It is unnecessary to go into the details of the test or methods employed, as these are given in the report of the test. It is sufficient to say that the test was properly conducted and particular care exercised in obtaining an accurate record of all quantities involved. The water and coal were weighed and the scales checked for accuracy at frequent intervals. All blowoff piping was disconnected from the boilers to preclude any possibility of error due to leakage. The boilers were subjected to regular normal operation except the rating was held at practically a constant figure, and no special effort was made to obtain an efficiency which would not be obtained under normal plant operation.

During the test the writer availed himself of the opportunity of watching carefully the boiler-room operation and also the operation of the pulverizing, drying and coal-handling equipment and was favorably impressed with the installation from an operating viewpoint.

The boiler-room operation was much simpler than is obtained with a stoker installation. The rate of steaming of the boiler is controlled by varying the speed of the feeder motor and adjusting the damper to take care of the different quantity of flue gas. It is unnecessary to look into the furnace at frequent intervals as is the case when firing with stokers and where holes in the fire or heavy spots must be corrected. In fact, when once the feeder speed is set to give a certain rate of steaming of the boiler, there seems to be no reason why this rating could not be maintained continuously so far as the furnace is concerned without it being necessary to make any changes whatever. Variations in the kind and quality of fuel burned seemed to have no effect on the operation except that when feeding at a constant quantity the rating of the boiler varied with the heat value of the coal. At one time during the test Youghiogheny was used, this coal having a higher heat value, higher volatile content, less ash and less sulphur than the mixture of Youghiogheny and Kentucky coal used throughout the remainder of the test.

Losses that are inherent in stoker practice, such as breakdowns in the stoker itself, breaking up clinkers, loosening clinkers, continually watching the fire to maintain correct and uniform thickness, watching the gas passes of the boiler for large sparks indicating the carrying away of combustible, dumping, and the many

*Presented before Technical League of Employes Mutual Benefit Association, T. M. E. R. & L. Co.

[1]See *Power*, Oct. 15, 1918, pp. 556-9.

other operations that are necessary in stoker operation, are eliminated. In other words, efficient combustion is obtained at all times without continual supervision by an experienced operator and from the standpoint of reliability of operation the odds are in favor of the pulverized fuel. This is an item for serious consideration in plants designed with 4.5 kw. capacity or more per installed boiler horsepower, where the losing of a boiler due to stoker trouble at the time of maximum load on the station, might seriously overload the remaining boilers or make it necessary to drop a portion of the load.

The handling of the ash resulting from combustion of the pulverized fuel is a simple matter due to the very small quantity that is deposited in the furnace. It is in the form of a fine impalpable powder which during the test was removed twice each 24 hours. On several occasions during the first and second days of the test, slagging occurred in a furnace due to not admitting a sufficient quantity of air. The direct cause of this was over-anxiety on the part of the men conducting the test to obtain a high percentage of CO_2 in the flue gas. The reduction in the excess air permitted the furnace temperature to rise to a point where slagging occurred. The removing of this slag from the bottom or floor of the furnace presented more difficulty than is usually experienced in removing the refuse from the ash hopper of a stoker-fired boiler. This slag had to be broken up and pulled out before it fused to the brick lining of the furnace. It appeared to the writer that this formation of slag could have been eliminated almost entirely by a more frequent inspection of the floor of the furnace and the admitting of more air through the openings in the front of the furnace if it was found that slag was beginning to form. Even at the time of removing this slag it was possible to maintain the rating on the boiler by increasing the coal feed. This, however, resulted in a decreased efficiency during the time required, amounting to about forty-five minutes in 24 hours for each boiler.

A large portion of the ash resulting from combustion is carried on through the passes of the boiler and out of the stack. Owing to the fineness of this ash it apparently is carried a considerable distance even in a moderate wind before being precipitated. Throughout the test there was a moderate wind blowing, probably between 4 and 8 miles per hour, and the writer was unable to find any noticeable deposit in the streets. Even at the time of blowing the deposit of ash from the boiler tubes, which was done three times a day, requiring about 20 minutes per boiler for each blow, no noticeable precipitation of ash could be found in the streets. At no time during the test was there any tendency for slag to form on the tubes of the boiler.

Strictly speaking, there is no such thing as a banked boiler when using pulverized fuel, as all that is necessary when it is desired to cut out a boiler is to shut off the coal feed and close all the dampers and auxiliary air inlets to the furnace. In this way the company has found by test that it is possible to hold the boiler up to pressure for about ten hours by the radiant heat stored up in the furnace and boiler setting which is gradually absorbed by the boiler. The loss which occurs and which can be compared to the banking loss in a stoker-fired boiler is the heat radiated from the boiler and setting, an equivalent in amount to that required to heat up the boiler and setting again to the temperature attained when steaming. In a plant where the ratio of boiler hours to boiler steaming hours averages 43 per cent or greater, which corresponds to an average daily plant load factor of 67 per cent, the saving resulting from the use of pulverized coal is worth considering. Assuming 0.2 lb. of coal consumed per boiler-horsepower-banking hour in a plant equipped with underfeed stokers, this loss amounts to about 1.5 per cent. In a pulverized-fuel-burning plant the loss should be reduced to one-half this figure, resulting in a net saving of 0.7 per cent on this one item alone.

Conveying and preparation of pulverized fuel presents a somewhat more complex problem, although the present equipment of the Oneida Street station is operating satisfactorily, and, during the test, operated without any serious interruptions. Moisture in the pulverized fuel, caused by sweating on the inside of the pulverized-fuel bins, resulted in some feeder troubles, but this was only a temporary condition and was overcome by closing the windows just above the bins, stopping the cold air from blowing directly on them. One of the feeder pipes between the bin and the furnace became partly plugged up due to a paper composition gasket becoming lodged in the pipe just above the burner. The boiler on which this occurred was operated for at least 24 hours at the desired rating by increasing the feeder speed on the other burner until the trouble was located and removed. During this period the efficiency of combustion was undoubtely below the average, as the coal that did come through the plugged feeder was not fed in with the correct quantity of air. No trouble was experienced with the drier or pulverizing mills at any time during the test.

The writer does not believe that under test conditions over a period of constant boiler rating the efficiency obtained with the use of pulverized fuel will exceed that which has been obtained from the best stoker practice under similar operating condition. However, under normal operation it is believed that the elimination of the many variable conditions entering into stoker operation will result in higher efficiency for the pulverized-fuel installation. Over-all efficiencies of boiler, furnace and grate as high as 82 or 83 per cent have been obtained on test with stoker-fired boilers, but normal operation day in and day out seldom exceeds 76 per cent in the very best practice where highly skilled help is employed in supervising the boiler-room operation. The gross over-all efficiency of boiler and furnace of 79.6 per cent, as obtained from the results of this test, would unquestionably have been higher had the boiler been cleaned prior to the test. As a matter of fact each boiler had been in operation prior to the test approximately 600 hours since being entirely cleaned, including approximately 300 hours on three of the boilers since cleaning the first four rows.

Certainly, the results obtained in the pulverized-fuel burning plant as a whole, where the equipment was installed and made to fit an old plant originally equipped with Jones stokers, are encouraging enough to warrant serious consideration of the use of this kind of fuel in stations to be built in the future. There are many improvements which can be made in a new plant, especially in the design of the furnace, location of the drying and coal-pulverizing equipment, method of coal handling and pulverizing, method of ash handling, slag prevention, possibility of using waste gases for the drying of fuel, all of which will have an effect on the efficiency which may be obtained. The application of pulverized fuel to central generating stations has been in use to a very limited extent for several years, but there still remains much experimental work to be done before we can hope to exhaust all the possibilities for increased efficiency, and bring it to as high a state of development as is the stoker at the present time.

EDITORIALS

Fatal Accidents on Low-Voltage Circuits

WHEN alternating-current systems first began to come into use, and the voltages of these systems were increased to eleven hundred or twenty-two hundred volts, there was considerable discussion of the question of limiting, by law, all electric circuits to one thousand volts and under, since an electric pressure above this value was considered too hazardous to work around. However, such legislation never was passed, and the voltages of electric circuits have increased until at the present time circuits operating at one hundred and fifty thousand volts are in service and the two hundred and twenty thousand-volt system is a possibility of the near future. Fatal accidents have occurred on circuits of less than one hundred volts, yet the average electrical worker will handle one hundred and twenty and two hundred and forty volt circuits with a sense of safety. Some industrial authorities recommend that not over two hundred and forty volts should be used on direct-current motor circuits.

A report made by G. S. Ram, electrical inspector of factories in England, contains some very interesting data on this subject. Out of ninety-nine fatal electrical accidents occurring in England during the period from 1915 to 1918, inclusive, twenty were on circuits of one thousand volts and over, while the other seventy-nine were on circuits of five hundred and fifty volts and less. Fifty-nine of these were on circuits having voltages between five hundred fifty and three hundred forty-six, and the remaining twenty happened on circuits of two hundred and forty down to as low as one hundred and five volts. Of the sixty-nine accidents occurring on circuits of four hundred and forty volts and less, it is doubtful if any of the fatalities were due to pressures greater than two hundred and fifty volts, since the voltage to earth on any of these circuits was not above the latter value. Ninety-five of the total number occurred on alternating-current circuits. This is probably due to the wide use of alternating current for industrial purposes. Since a direct-current machine or starting device is not in general as well insulated to prevent getting in contact with bare parts as alternating-current equipment, there is always greater danger of receiving a shock from the former than from the latter. The direct-current machine always requires more or less attention while in operation, such as sandpapering the commutator and adjusting the brushes, which is not required on polyphase alternating-current machines. However, in all low-voltage alternating-current circuits there is always danger of the insulation between the primary and secondary of transformers breaking down and subjecting the secondary to primary volts to ground, a dangerous condition unless the secondary winding is grounded.

Since the probable voltage of the shock in sixty-six of the foregoing cases was between two hundred fifty and two hundred volts, it would seem that these voltages are as dangerous as five hundred and fifty volts. One of the greatest dangers of accidents from electric circuits is the disregard that a large majority of workmen have for low-voltage circuits, which develops from knowing that under ordinary conditions a serious shock will not be received from these circuits. However, if a low-resistance circuit to ground is made and the individual cannot readily get clear of the circuit, there is danger of as low as one hundred and ten volts or even less causing fatal accidents, therefore such circuits should always be treated as hazardous.

Pulverized Coal at Milwaukee

THROUGH many vicissitudes pulverized coal in the power plant has at least reached the stage where it may be pronounced a commercial success, although there still remains much experimental work to be done. The numerous difficulties that have blocked the way have been overcome gradually, and it has been proved beyond peradventure that coal in the powdered form can be burned to advantage over the most modern and recent methods of combustion. The general increase in the price of fuel has been the immediate incentive. Under test conditions the efficiency of burning is only a trifle higher than in the modern type of stoker, but in daily operation the elimination of the many variable conditions entering into stoker operation, the flexibility and the ease of control and other inherent advantages are reported to give to powdered coal a margin that will more than offset the higher cost of fuel preparation and the additional investment in equipment.

The glory goes to Milwaukee and in particular to the men who have struggled for two years to make the previous claims possible. It has not been an easy task, and there were times when the difficulties seemed almost insurmountable. Five times the furnaces were changed in shape and volume and additional provision made for the admission of air to improve combustion and protect the brickwork in the furnace before the present satisfactory results were obtainable. The furnace volume selected, 0.359 cubic foot per square foot of water-heating surface, is not excessive when it is considered that it is equivalent to the furnace and ash-pit of a stoker.

Re-equipping five boilers in an old plant made the work more difficult than it would have been with an original layout. The story is told on other pages of this issue. A résumé is given of the requirements and the advantages. There is a summary of a four-day test on all five boilers under average operating conditions, and to confirm the reliability of methods and figures, there is comment from a competent observer of the test attached to one of the largest and best-equipped stoker plants in the country. The proof of the pudding is in the eating, and in this case the verdict has been so favorable that the new Lakeside plant of the Milwaukee company will be equipped to burn pulverized fuel. As an initial installation it is to have eight 1,306-horsepower boilers, two 20,000-kilowatt generating units and a separate building for the preparation of fuel. The coal consumption will approximate seven hundred tons per day. The added investment in building and equipment for preparing the fuel over a stoker plant has been estimated to exceed twenty dollars per

boiler horsepower, but the saving possible, based on improvements suggested by operation at Oneida Street station, indicates that this additional expenditure will be well worth while. A more exact statement of the possibilities will be available at a later date.

Referring again to the opinions of the men responsible for the progress made and of those who had an opportunity to inspect the plant at its present stage of development, it would appear that boiler-room operation when burning powdered coal is much simpler than with a stoker installation. The rate of steaming is controlled by varying the speed of the feeder motor and adjusting the damper for the variation in the quantity of flue gas. It is unnecessary to correct the holes and heavy spots that develop in the fuel bed of a stoker; and variations in kind and quality of fuel burned seem to have no effect on operation except that with a constant feed the rate of steaming will vary with the heat value of the coal. Losses inherent in stoker practice, such as breakdowns in the stoker itself, breaking up and loosening clinkers, watching the fire to maintain uniform thickness, dumping and many other operations, are eliminated. Efficient combustion is maintained without continual supervision by an experienced operator, and from the standpoint of reliability the odds have been placed in favor of pulverized fuel.

With coal and air supplies easily adjustable, almost perfect fire control and proper air distribution are obtained. This results in thorough combustion, uniformly high efficiency under normal operation and the ability to change from no load to two-hundred per cent overload in a few seconds. Regularity of action, making it possible to anticipate results, is a factor that appeals to the operator.

With powdered coal, banking a boiler is a simple process, requiring no additional fuel to hold the fire. It is necessary only to stop the fuel supply and close the dampers and auxiliary air inlets. The radiant energy in the brickwork is retained and will hold pressure on the boiler for hours.

Observation for a period of two years in the installation under discussion has demonstrated that the brickwork in a pulverized-fuel furnace will stand up equally as well as in a stoker installation, with the added advantage that ironwork is eliminated from the high-temperature zone of the furnace. Maintenance exists principally in the pulverizing plant. With machinery of the slow-moving type it is not excessive, although there is room for improvement.

Owing to the soft heat and no impingement of the heat on the tubes caused by a strong draft, the formation of scale in the boiler seems to be less. There is absolutely no trouble from smoke and no soot to reduce the heat-absorbing ability of the boiler, although there is some collection of very light ash. Much of the ash apparently floats out of the stack, leaving a comparatively small amount to be removed from the combustion chamber. It is interesting to note that the low moisture content of the coal as fired reduces the opportunity for the formation of sulphuric acid, so destructive to all ironwork with which the flue gases come in contact.

That there has been no serious trouble from coal-dust explosions is attributed to proper care in preventing the coal from being dried too much or pulverized to a fineness beyond the requirements. The drying process requires careful supervision and ability in the operator to recognize and meet the varying properties of the coal as it arrives. Drier operation must be changed to meet variations in size and moisture if a uniform product is to be delivered. Coal that is too dry increases the danger from explosion, and too much moisture induces a tendency toward clogging the system at points most readily affected. At Milwaukee moisture has been one of the bugbears encountered.

No claim is made that perfection has been reached in the present installation or that other designs of equipment might not work equally well or possibly better. Valuable experience has been gained, however, and the next installation will contain a number of improvements. It is felt that something might be done toward reducing the cost of preparing the fuel, especially along the lines of utilizing waste gases for drying in plants not provided with an economizer. A furnace that would burn a large percentage of finely divided coal and still care for a smaller amount of larger-sized particles would be a decided advantage, as it would reduce the work of the pulverizer, which requires about seven-eighths of the total electrical energy consumed by all moving parts of the coal-preparation equipment, and also curtail the labor in this department.

Admission of excess air to prevent slag formation and the destruction of the brickwork tends to lower the CO_2 and reduce to some extent the efficiency of combustion, or at least the absorption by the boiler due to the lower heat head. There is an opportunity here for improvement. A more thorough mixing of the air and fuel in proper proportions before entrance into the furnace may be the solution.

The proper furnace volume per square foot of steam-making surface or per unit of coal burned, the position of the furnace relative to the boiler, the location of the burner, whether vertical or horizontal, the best methods of mixing coal and air, location of equipment, etc., are all factors requiring more study. These are the problems of the future. Suffice it to say that the plant which has been made a success at Milwaukee, has paved the way. The pioneer work has been done. There remain perfection of detail and experimental work to exhaust the possibilities for increased efficiency.

An interesting point is the conclusion that a plant developing less than twenty-five hundred boiler horsepower on a twenty-four hour operating basis should not consider using powdered coal. The reasons advanced for this limitation are the cost of installation, the relatively small amount of coal pulverized per day and the proportionately large labor charge for operating the preparation plant.

A few weeks ago in Milwaukee a federation of technical engineers, architects and draftsmen pledged themselves to uphold and sustain the principles adopted by the American Federation of Labor. They were determined to have a voice in the adjustment of disputes in all industries of which they were a part and use, if necessary, the powerful backing of labor. The reward of individual merit, coöperation or the policy of "suggestions" for mutual benefit, had no place in their sympathy. In brief, force is the guiding spirit. On the economic position of the engineer the American Association of Engineers takes the attitude expressed on other pages of this issue. Being a constructive agent, it is their belief that the engineer should be opposed to strikes, which in their very nature are destructive. For just reward of individual effort he should depend upon the justice of the facts, presented collectively if necessary, upon enlightenment of public opinion, upon loyalty between employer and employee and upon the fundamental desire of the great majority to do what is fair and right when the merits of the case are clearly presented. For a dignified profession there is only one choice between the tenets of the two organizations.

CORRESPONDENCE

Engine Running Twenty Years

On page 668 of the Oct. 28-Nov. 4, 1919, issue of *Power,* Mr. Molloy states how satisfactorily his engine runs and mentions the fact that he does not intend to overhaul it if it does not need it.

I presume Mr. Molloy has lately run a test on this engine or keeps a close record of operating costs, and that his statement is based on the unit's performance. No doubt these data would prove interesting reading in comparison with the same relative values obtained with more up-to-date equipment, and I am sure that many readers besides myself would be glad to see these figures in *Power* if Mr. Molloy could be induced to submit them for publication. ROBERT W. RIORDAN.

Brooklyn, N. Y.

When the Ground Indicators Deceived

In a large generating station each alternator had two sets of ground lamps connected across its exciter; one set on the main switchboard, the other on a power-supply switchboard on the turbine-room floor. Each set consisted of two 250-volt lamps in series, with the wire common to both lamps grounded, as in Fig. 1. Shortly before peak-load time one afternoon, the switchboard

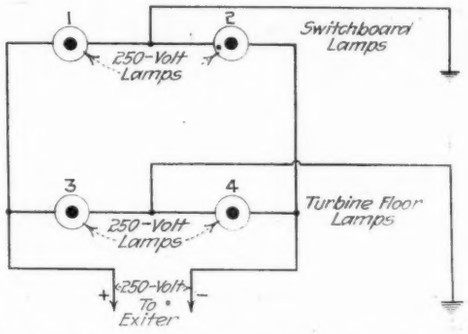


DIAGRAM OF GROUND-DETECTOR LAMPS

ground lamps of one of the units began to flicker, and a warning was given that the unit had a swinging ground on its field.

The ground seemed to clear itself in a short time, only to immediately return and become solid. The filament of lamp 1 was barely red, while lamp 2 was at full brilliance, indicating a positive ground. Both lamps normally burned at half brilliance since, being connected in series across a 250-volt circuit, they operated at only half voltage. At the time of the trouble no one gave thought to the scheme of connections, or remembered to check the switchboard lamps against the set in parallel with them on the turbine floor.

While arrangements were being made for a reduction of load on the station, in anticipation of trouble with this unit, an electrician passing the turbine-room lamps noticed lamp 4 dead and lamp 3 dim. He twisted the dead lamp in its socket and both sets of lamps came back to normal. Vibration had loosened lamp 4 in its socket, causing the other three lamps to flicker; and when the circuit was broken at lamp 4, lamps 1 and 3 became dim and lamp 2 bright. FRANK GILLOOLY.

Philadelphia, Penn.

Leaky Safety-Valve Seats

If a safety valve leaks after having been reseated or ground in, an examination may show that the leakage occurs between the seat and the valve body. When the valve is cold, the seat may be found to be quite loose. This may be accounted for by the fact that the unequal expansion of the bronze seat and iron body compresses the seat. If the seat seems to be tight, it is a good plan to invert the valve and fill it with water in order to locate any leakage.

The remedy for a loose seat is to expand it with an ordinary tube expander. If the seat is of sufficient length, the expanding should be done below the top of it Afterward the valve should be reseated and ground in in the usual manner. Some types of globe and angle valves can be repaired in the same manner.

Providence, R. I. C. P. LAWTON.

Why Does the Water in a Boiler Lift When the Safety Valve Blows?

Referring to Mr. Fryant's inquiry in the Nov. 11-18, 1919, issue, would say that I have given the subject of water lifting in a boiler much thought and study, and it is my opinion that high or low velocity of the steam leaving a boiler has no effect on the moisture carried over; but it is the quantity of steam delivered in a unit of time, together with the liberating surface of water. The smaller the drum, or shell in which the steam is liberated from the water in proportion to the quantity of steam delivered, the greater the moisture. Then the position of the nozzle or outlet flange on the drum or drums of water-tube boilers has quite an effect on the moisture, as the farther the steam travels before it enters the outlet the drier it is. The kind of dry pipe also has quite an effect. Some dry pipes are collectors of moisture instead of eliminators. I have taken some dry pipes out over nine feet long, which delivered very wet steam.

The height of the water line in water-tube boilers in which the drums are set on an incline affects the moisture, and the higher the water is carried (within reason) the drier the steam. This is caused by the steam and water spouting up through the water in the drum when the water is low, which it cannot do when the water is high. The steam outlet is generally right over where the water and steam is liberated from the tubes in this type of boiler, therefore the steam has a very short travel to the outlet and does not have time to drop its moisture.

There is no doubt about the steam being drier where the velocity in the pipes is high and the drop in pressure is high, because this drop causes the entrained water to be evaporated by the excess heat in the steam over what it was at a higher pressure, just as is done in a throttling calorimeter.

J. T. FENNELL.

Philadelphia, Penn.

Power-Plant Log Sheet

In the Sept. 16, 1919, issue of *Power* there was published an article entitled "Boiler- and Engine-Room Record Sheets." This article described and illustrated four record sheets designed by the author for use in the boiler and engine rooms of power plants under his supervision.

Later, it has developed that with a large number of plants reporting to one supervising officer, the amount of clerical work, checking and figuring on four reports could be dispensed with in favor of the revised form shown in Fig. 1, which has been put in use to replace the four forms previously mentioned.

Fig. 2 shows a running record form by months and years of the fuel consumed, value and per cent of increase or decrease in fuel per year, for comparison of four years. The figures are transmitted from the log

POWER PLANT LOG SHEET

_____ Station Month of _____ 19____

Day of Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals
No. boilers in service																																
No. boilers closed down																																
No. boilers not blown																																
No. boilers blown down																																
No. boilers washed																																
No. boilers turbined																																
No. tubes renewed																																
No. grates renewed																																
Condition baffles																																
Condition furnace																																
Condition settings																																
Condition blow off system																																
Condition pumps																																
Condition combustion chambers																																
Average steam pressure																																
Average feed water temperature																																
Boiler No. 1—Hours operation																																
Boiler No. 2—Hours operation																																
Boiler No. 3—Hours operation																																
Boiler No. 4—Hours operation																																
Boiler No. 5—Hours operation																																
Boiler No. 6—Hours operation																																
Generator No. 1—Hours operation																																
Generator No. 2—Hours operation																																
Generator No. 3—Hours operation																																
Air compressor No. 1—Hours operation																																
Air compressor No. 2—Hours operation																																
Air compressor No. 3—Hours operation																																
Average air pressure																																

Engineers	1st	2nd	3rd	Total Man Hours	Value
Oilers					
Firemen					
Helpers					
Ash pit men					
Flue blower					
Boiler washers rate					
Helpers rate					
Boiler makers rate					
Helpers rate					
Machinists rate					
Helpers rate					
Pipe fitters rate					
Helpers rate					
Masons rate					
Helpers rate					
Electricians rate					
Helpers rate					
Laborers rate					
Engines oil—Gallons received					
Steam cyl. oil—Gallons received					
Air cyl. oil—Gallons received					
Crank case oil—Gallons received					
Cup grease—Pounds received					
Waste—Pounds received					
Packing steam—Pounds received					
Packing water—Pounds received					
Packing sheet—Pounds received					
Hand hold gaskets—No. received					
Pump valves—No. received					
Brooms, scoops, rake, hoe, slice bar hook					

FUEL—CARS OF COAL UNLOADED Total

Car Initial	Car Number	Net Weight	Mine Location or name	Car Initial	Car Number	Net Weight	Mine Location, or name	Car Initial	Car Number	Net Weight	Mine Location, or name	Car Initial	Car Number	Net Weight	Mine Location or name

ELECTRIC POWER AND INTEGRATING WATT METER READINGS

	Power—A.C. Generator No. 1—Lights		Power—A.C. Generator No. 2—Lights		D.C. Gen. No. 3	Motor Gen. Set	Purchased Current
Meter Readings, End of present month							
Meter Readings, End of last month							
Output Kilowatt Hours							
Repairs to pumps							
Repairs to boilers							
Repairs to engines							
Repairs to piping							

Signed _____ Eng. in charge

Signed _____ Supr. Power Plants

FIG. 1. A REPORT SHEET THAT DISPENSED WITH FOUR REPORT SHEETS

sheet and are inserted monthly for ready reference of the management, to show at a glance what is being done each month in the matter of fuel economy. The load at all plants is not of such variable nature as to have much effect on fuels consumed.

Fig. 3 shows a statement of money expended for power-plant labor, together with the number of man-

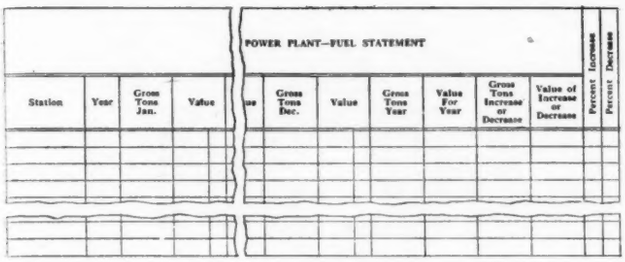


FIG. 2. RUNNING RECORD FORM BY MONTHS AND YEARS

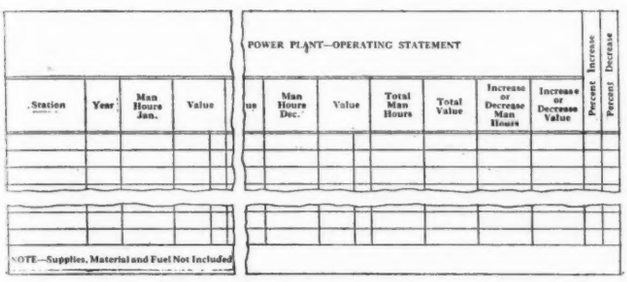


FIG. 3. MONTHLY LABOR EXPENSE SHEET

hours required. This information is also obtained from the log sheet.

Checking statements such as this, together with similar statements, are helpful in indicating just what each plant is doing, and with recording flow meters, pressure and temperature recorders, etc., an efficient operation can be maintained.

Hagerstown, Md. PAUL R. DUFFEY.

Blowing Down Boilers

I read L. A. Cole's letter in the Oct. 21, 1919, issue of *Power*, page 265, and from my point of view and experience Mr. Cole displays very good boiler logic. The blowing down of a boiler should be governed according to the conditions of the water. Water that is not treated before it is fed to the boiler will naturally deposit more dirt, scale and sediment than water that does not have to be treated. Such loose scale and dirt as is liberated in the boiler should be removed, and the way to do this, when a boiler is being worked up to its capacity, is to blow down at least every three hours.

If a suitable boiler-feed water is used, blowing down once a day is sufficient; otherwise the boilers should be blown down at such intervals as will remove such mud, scale and sediment as will flow to the blowoff valves under an ordinary blowdown. There can be no fixed rule as to the amount of water that should be blown from a boiler at one time.

The noise mentioned by Mr. Cole in the blowoff pipe when he first begins to blow down is caused by an accumulation of hard pieces of scale around the blowoff pipe outlet, and when the valve is first open this accumulation of scale is blown out through the pipe.

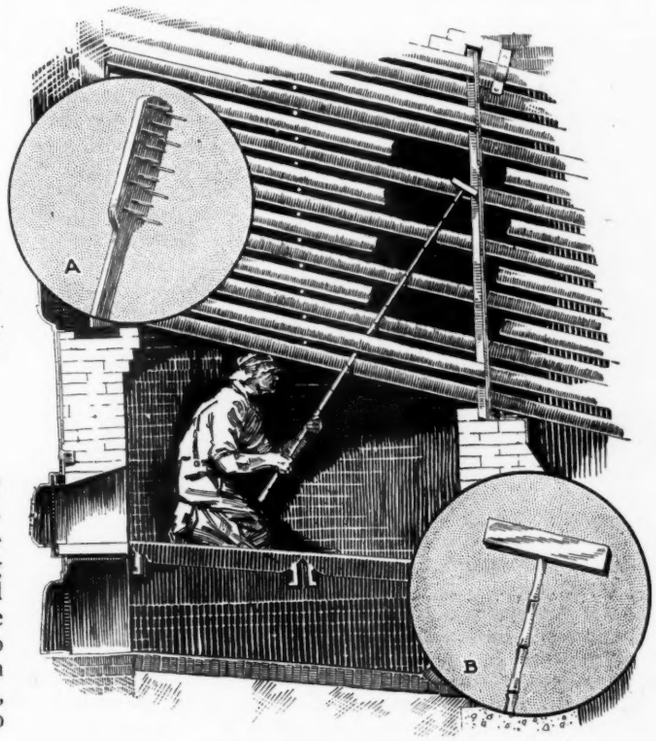
Brenham, Tex. H. W. ROSE.

Home-Made Baffle-Wall Mixture

I have read from time to time of trouble with boiler baffles, and I have had difficulty in keeping them from burning away at the first pass up to the fourth and fifth rows of tubes. We bought about everything on the market that was supposed to be able to stand up, but could not get the desired results. I therefore took it upon myself to create a mixture that has stood a very severe test, as our boilers are forced much above their rating for about six hours each night.

I used a mixture made up as follows: About 200 lb. of clinkers that were thoroughly burned and showed symptoms of having been heated to the melting point were crushed to a size not larger than rice coal. Then about 100 lb. of dry sand was thoroughly mixed with the ground clinker. Next I obtained 50 lb. of glass and put it into a box and powdered it as fine as possible. This was then mixed with the sand and cinders, after which 50 lb. of good-quality portland cement was added, and after being thoroughly mixed about 25 lb. of fine dry asbestos was added. The batch was turned over and over until the materials were thoroughly mixed in a dry state.

When ready to apply the mixture, a stick of ¾-in. stock as shown at *A* was obtained, in the head of which No. 10 nails were driven about two inches apart and



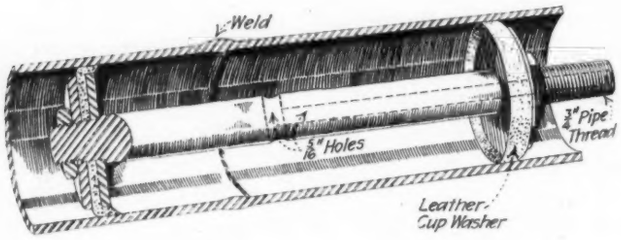
APPLYING THE BAFFLE MIXTURE

all the way through. The mixture was then wet just enough to make a stiff paste and a wad placed on the nails, run up between the tube and slapped into place, and the operation repeated until the job was finished. After a portion of the baffle was covered I used a tool made of a block of wood 2 in. wide, 5 in. long and 2 in. thick, having a handle about 3 ft. long, as shown at *B*. A bamboo fishpole makes a good handle. This was passed up between the tubes and used to hammer the mixture in tight and of a smooth and uniform thickness.

New Rochelle, N. Y. B. GADDIS.

Weld-Testing Device

In order to test welds in boiler tubes, the device illustrated was made. It consists of two pistons, made as shown, one to come on each side of the weld. A rubber hose is attached to the rod projection, and com-



DESIGN AND APPLICATION OF TUBE TESTER

pressed air is admitted through the hollow rod and outlets. Thick soapsuds are applied to the tube over the weld, and if a leak is present bubbles will form. No defective welds have got past since the tester has been used, whereas before its use several tubes had to be removed after they had been put in the boiler and steam raised.

R. McLAREN.

Toronto, Canada.

Commutating-Pole Motor Trouble

A new commutating-pole shunt motor was installed to drive a centrifugal water pump. The motor was rated at 21.5 amperes, but frequently, when the machine was started, the 30-ampere fuses protecting the motor were blown. Investigation showed that the motor

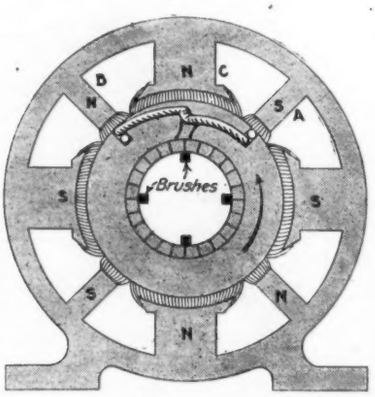


FIG. 1. INTERPOLE MOTOR WITH BRUSHES LOCATED IN CORRECT POSITION

speed was too high. The trouble was overcome by shifting the brushes forward, thus reducing the speed and current to their proper values. It is particularly important that the speed of a centrifugal pump be correct, as the power required to drive it varies with the cube of the speed. It is also important that the brushes of a commutating-pole motor be properly set. A greater effect is produced in a commutating-pole motor than in a noncommutating pole by incorrect brush setting. The theory of this change of speed in an interpole motor is as follows:

When the brushes are in the correct position, as shown in Fig. 1, the coils on the armature between commutating poles *A* and *B* are cutting flux from the main pole *C*. If they cut any of the flux from the commutating pole *N*, they also cut an equal number of lines of force from the *S* commutating pole, hence the voltage in these coils is not influenced by the commutating flux. But if the brushes are shifted backward to a position as in Fig. 2, the coils between the sides of the coil under commutation will be cutting the flux of the main *N* pole *C* and also from the flux from the *S* commutating pole *A*, thus decreasing the effective volts gen-

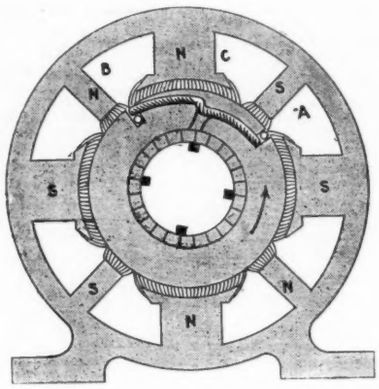


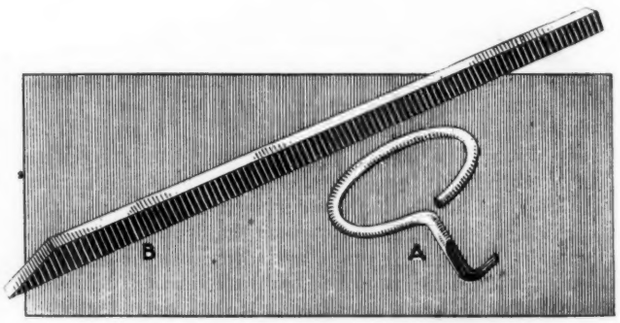
FIG. 2. INTERPOLE MOTOR WITH BRUSHES LOCATED OFF CORRECT POSITION

erated in these coils and causing the speed to increase. If the brushes had been shifted forward, the speed would have been decreased.

Washington, D. C. H. L. HERVEY.

Removing Retaining Wedges and Coils from Induction Motors

The following method for removing slot wedges and coils from stators has been used with considerable success. Nearly all insulating varnishes and paints are softer when warm than when cold, hence the coils and wedges can be removed more easily if the frame is heated. To loosen the wedge a drift of iron or fiber about $\frac{1}{32}$ in. narrower than the slot and five or six



TOOLS FOR REMOVING COILS

inches long is placed on top of the wedge and tapped with a hammer. After the wedge has been loosened over its full length, it can be driven out by driving on its end with a metal drift.

In removing the coils the greatest difficulty is with the first one. In order to start this coil the hook tool, as shown at *A*, is used to lift the coil ends as high as they will go. The pointed tool *B* is then inserted under the coil at the end of the slot, and the coil is raised.

Washington, D. C. H. L. HERVEY.

INQUIRIES OF GENERAL INTEREST

Enlargement of Crankshaft Diameter—Why are crankshafts of engines made larger at the center than at the ends? J. W. H.

Crankshafts have enlarged diameters at the middle of their length to afford greater strength and stiffness in resistance of bending stresses due to the weight of the flywheel, and tension of belt or thrust of driving gears, and also to compensate for the reduction of strength from removal of material for a keyway.

Handholes for Vertical Fire-Tube Boilers—How many handholes should there be in a vertical fire-tube boiler? G. L. S.

Boilers more than 24 in. in diameter should have not less than seven handholes; namely, three in the shell at or about the line of the furnace crown sheet, one in the shell at or about the water line or opposite the fusible plug when used, and three in the shell at the lower part of the water leg.

Additional Steam for Increased Back Pressure—How does increase of back pressure affect the quantity of steam required by an engine? J. R. A.

For the same load on the engine each pound of additional average back pressure will require an additional pound of average forward pressure, so that to meet an increase of back pressure, the supply of steam will have to be increased as much as though the load had been increased to require the same additional mean effective pressure.

Forward Pressure, Back Pressure, and M.E.P.—What is meant by the terms average pressure, mean forward pressure, mean back pressure and mean effective pressure of an engine? W. P. S.

The word "mean" is to be understood to signify simple average. The pressure that urges a piston forward in the direction that it travels in performing useful work is called forward pressure, and the average forward pressure is frequently designated as the mean forward pressure. Pressure that opposes the motion of the piston in performance of useful work is called back pressure, and the average back pressure is also called the mean back pressure. The difference between the mean forward pressure and the mean back pressure is called the mean effective pressure.

Carbon Brush Wear—In one of our direct-current motors that has four brushes on the commutator, two of the brushes wear away faster than the other two. What would cause this uneven wear when all four brushes are of the same grade? T. A.

The brushes from which the current flows into the commutator always wear away faster than those through which the flow is from the commutator. The brushes through which the current flows into the commutator would be positive on a motor and negative on a generator. The additional wear on these brushes is due to small particles of carbon carried by the current from the brush contact surface and deposited on the commutator. If two of four brushes, of the same polarity, were to wear away faster than the other two, a difference in resistance in the shunts from the brushes to the brush-holder, or a difference in the tension on the brushes, would cause an unequal distribution of the current between the brushes and unequal wear.

Starting-Compensator Oil—What is the best grade of oil to use in starting compensators employed on 220-volt induction motors ranging in size from 10 to 75 hp. Would a poor grade of oil cause the contacts to burn? M. C. R.

In compensators employed for starting squirrel-cage motors a mineral oil having a high flash point should be used; it should be free from any trace of alkali or acid and have a low factor of evaporation. Under operating conditions the oil should not form deposits in the tank. One of the surest ways of securing the proper grade of oil is to obtain it from the manufacturers of the compensators. The design of the contacts, operating conditions and application of the compensator in general have a much greater influence on the burning of the contacts than the grade of oil. If the contacts are designed to give a rubbing make-and-break and the compensator is not abused either through improper handling or misapplication, little trouble should be experienced with burning and pitting, although a certain amount of this will occur under the best of conditions. In general the oil should be changed when it turns dark in color and sediment forms in the bottom of the tank.

Flashing Point of Fuel Oil—What is meant by the flash point of a fuel oil, and what do the "open" and "closed" tests consist of? W. T. D.

The flashing point of an oil is that temperature to which the oil must be heated, at a specified rate, to cause it to give off a vapor which will ignite when mixed with air and exposed to a flame near the surface of the oil. The "open test" consists in heating some of the oil, in which the bulb of a thermometer is placed, in a small open metallic cup, a porcelain crucible embedded in sand or some equivalent contrivance, heated by application of a gas flame or other source of heat that is under the control of the experimenter so that the temperature of the oil increases at the rate of 10 deg. F. per minute. A small flame from a taper or gas tube is passed across the surface of the oil for every five degrees rise in temperature until the vapor ignites or flashes. The temperature at which this flash is first observed is taken as the flashing point of the oil. The open-cup method is beset by uncertainties. The temperature at which the first flash is obtained depends on the presence or absence of air currents, the actual rate of heating, the size and shape of the vessel containing the sample, the distance of the flame from the oil surface and the skill of the experimenter.

The closed test, as the name implies, is performed with apparatus from which air currents are excluded and in which the oil and vapor are stirred and the heat applied may be so regulated that when the temperature nears the flash point, the rise in temperature is so reduced that the testing flame may be quickly applied to the surface of the oil every two degrees rise of its temperature until the flashing point is reached.

Open-cup testing usually gives 5 to 25 degrees higher flash point than closed-cup testing, and the presence of much moisture causes irregular and incorrect results by either method of testing.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Emergency Fleet Corporation Water-Tube Boilers for Wood Ships*

By F. W. DEAN and HENRY KREISINGER

This paper describes and reports tests upon the Standard water-tube marine boilers planned by the United States Shipping Board, Emergency Fleet Corporation. It also reports the results of special investigations of the mixture of air and combustible gases in the furnace and of the temperature of the gases.

IN 1917 the Emergency Fleet Corporation intended to build one thousand wood ships of 3,500 tons dead-weight capacity. Each ship would require two boilers containing about 2,500 sq.ft. of heating surface each. The problem of securing two thousand good-sized boilers was a serious one, and naturally caused careful consideration of the relative merits of the water-tube and of the Scotch boiler. It was finally decided to use water-tube boilers, and to show the saving in steel caused by this decision, the weight of that metal in one of these boilers, with casing, is 41,200 lb., while for the equivalent Scotch boiler it is 110,000 lb. Although finally only 1,352 boilers were ordered, the saving of steel by the use of the water-tube type was more than nine million pounds. Furthermore, the adoption of the water-tube type rendered most of the inland boiler shops of the country available for this work, since this type could be transported easily. Another great advantage of this design came from the fact that all the boilers in the first lot of 706 units were alike, and differed only slightly from the later orders of 646 units, which were also alike. The differences in the design came from changing the number of baffles from three to four and in using Key handhole caps instead of plugs with copper ferrules.

The boiler as first designed is shown in Fig. 1. It consists of two headers each composed of two plates connected at the edges by channel-shaped pieces, the two headers being connected by tubes. The front header is surmounted by a saddle, which is riveted to both the steam drum and the header, and holes in the bottom of the drum, within the limits of the saddle, furnish the means of connecting the interior of the drum and the header, and two rows of so-called circulating tubes connect the upper part of the back header with the drum and serve to conduct the steam to it.

The header plates were stayed by means of hollow iron stay-bolts, the holes being ¾ in. in diameter. The handholes of the first 706 boilers were closed by means of taper plugs surrounded by thin copper ferrules. The plugs had a threaded shank secured by a yoke and nuts, as usual for handhole plates. While these plugs have in general given satisfactory

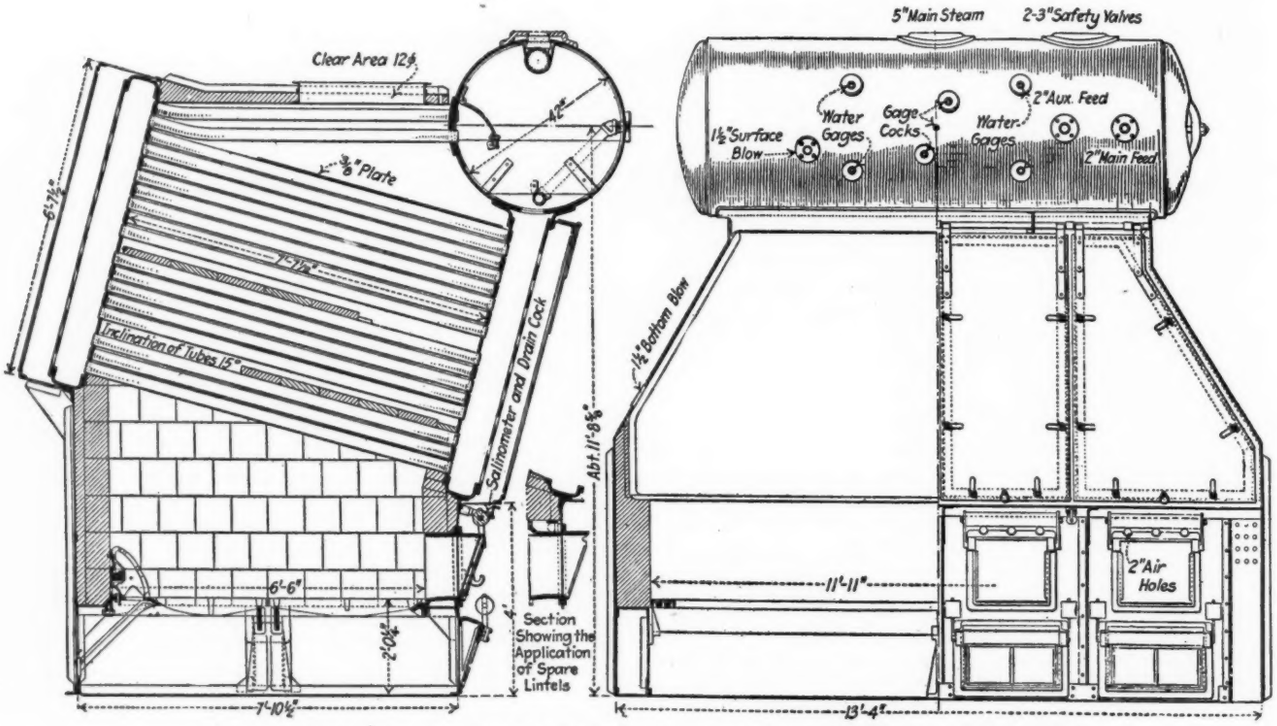


FIG. 1. THREE-PASS STANDARD WATER-TUBE MARINE BOILER FOR WOOD SHIPS

service, it was recognized that the Key cap is better, and all boilers afterward ordered were provided with these caps.

The drum was made with the longitudinal joint where the circulating tubes entered, there being here an inside and an outside strap, and the expanding occurred only in the straps, since the holes in the shell are larger than the tubes. The tubes are seamless hot-rolled steel. The baffles are of the longitudinal type, of which the first boiler mentioned has three, forming three passes, as shown in Fig. 1. After some testing, it was decided to place the lowest baffle on the lowest row of tubes in order to render the second and third rows of tubes more active as heating surface. When this change was being made, it was seen that there was room for four passes, and accordingly four baffles were inserted. This rendered the boiler somewhat more efficient, especially at the higher powers.

In the three-pass boiler the upper baffle was of steel plate and the others of tiles, but in the four-pass boiler the two upper baffles were of steel, and the indications are that the others might be of steel also if the tubes were sufficiently near together to touch the baffles on both sides. By using the steel

*Abstract from a paper read before the American Society of Mechanical Engineers at the Annual Meeting, December, 1919.

baffles in the four-pass boiler, 34 more tubes could be put in. In the drum of the four-pass boiler there is the usual deflector-plate, which compels the steam as it comes through the circulating tubes to pass to the end of the drum. This deflector was removed for a time, and no difference in the behavior of the boiler could be observed except that the water as it appeared in the glass was livelier. In a seaway other advantages might appear. In the top of the drum was a perforated dry pipe having eighty-eight ⅜-in. holes, and tests with and without this dry pipe proved that it had an important effect in separating moisture from the steam. At ordinary rates of working the loss in pressure amounted to little, but when forcing, it occasionally reached to six or eight inches of mercury for a short period.

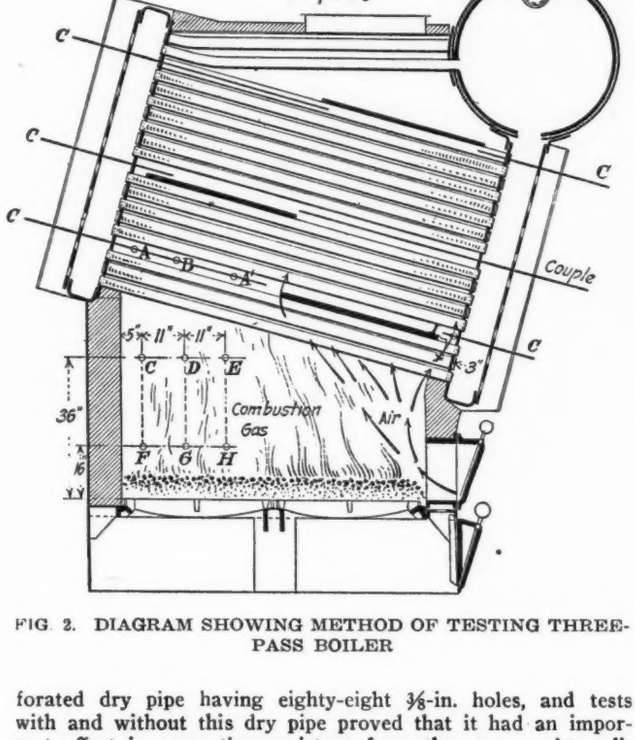


FIG. 2. DIAGRAM SHOWING METHOD OF TESTING THREE-PASS BOILER

The casing of the boiler is made up of steel plates joined together by external and internal shapes secured to a channel frame at the bottom, which rests on the keelson of the ship. At the front there are two vertical channels acting as columns, which are secured to the channel frame and bolted to tees riveted to the bottom of the header. The rear header rests on a shelf formed in the casing. The front column forms the only rigid connection to the channel base, and the boiler is free to slide in the rear part of the casing. In the front and back of the casing are sheet-iron doors covering the headers, and soot blowers are installed between the headers and the doors.

In the three-pass boiler there are four fire-doors and four ash-pit doors, but in the four-pass boiler there are three of each. These doors are of the inswinging type. Above each is a hollow perforated lintel with air entering through holes in the casing, and on the sides of the door there are perforated jambs with air supplies from the outside. These air openings are all useful in protecting the parts from burning and they also promote economy, for none too much air enters the furnace through them.

The grates are of the fixed type of double bars in two lengths and have ½-in. air and ½-in. iron spacing. Across the back end of the furnace there is a cast-iron bridge-wall with narrow air spaces, which saved nearly 2 per cent of coal, perceptibly diminished smoke, improved gas analysis, saved the brickwork and reduced the time and labor of cleaning fires nearly 50 per cent.

The leading dimensions of the boiler are given in Table I.

The tests described here were made for the purpose of studying the behavior of the boiler and, if possible, improving it. In connection with this work the Bureau of Mines has named Henry Kreisinger to take charge of the high-temperature measurements and the various investigations in connection with the paths and velocity of the gases, the draft magnitudes, losses through the passes, the advisable quantity of air and position of its admission.

Georges Creek, Cumberland coal from the Big View vein, was used on all tests in order to have a standard coal of uniform quality. Tests were made with fixed grates, shaking grates, without a bridge-wall, with the iron bridge-wall and with the brick bridge-wall covering the same area. Tests were also made with several kinds of oil furnaces using Mexican oil.

By the addition of the iron bridge-wall, admitting air around the fire-doors, lengthening and otherwise changing the baffles and studying the method of firing, the efficiency of the three-pass boiler was raised from about 60 per cent to about 71 per cent based upon dry coal, and the efficiency of the four-pass boiler was about 72½ per cent based upon dry coal. These tests were made when firing by hand.

Results of the Tests

Tables II, III, IV and V show the general results of the tests of the three-pass and four-pass boilers under various conditions, both with hand and stoker firing.

Tests were run at various rates to determine the effect of forcing on the economy. In one the four-pass boiler was worked at 131 per cent of marine rating and 229 per cent of land rating. Even at this high rate the efficiency was about 71 per cent and but little below that of lower rates. With stokers the boiler was operated at 162 per cent of marine rating and 282 per cent of land rating, and at this rate the efficiency was 73.3 per cent based upon combustible. The test of Apr. 8 shows a very high efficiency, but this is open to suspicion because the heat balance did not work out quite properly, due, it is thought, to an error in the coal weight of one hour.

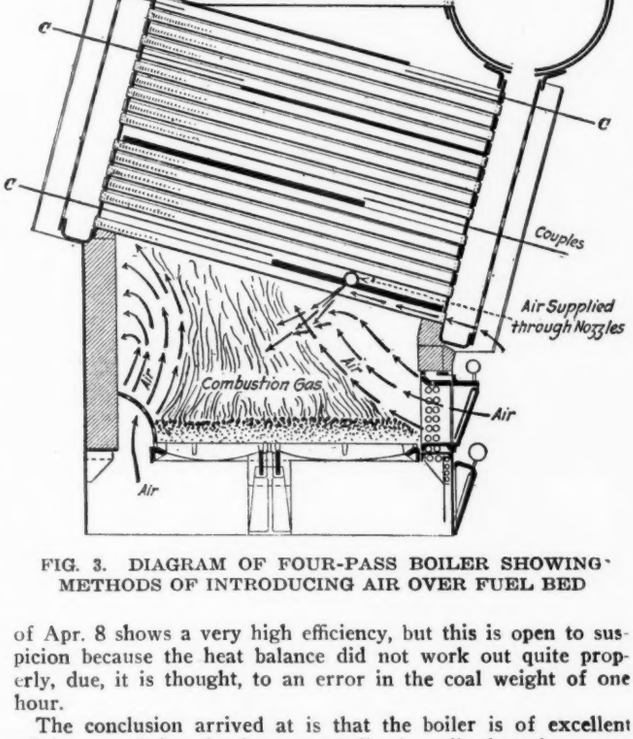


FIG. 3. DIAGRAM OF FOUR-PASS BOILER SHOWING METHODS OF INTRODUCING AIR OVER FUEL BED

The conclusion arrived at is that the boiler is of excellent efficiency and that the four-pass boiler is well adapted to overload. The only defect of the latter is, as might be expected, that there is considerable absorption of draft in the passes, and the greatest loss was in the third pass from the bottom.

As an experiment half of the circulating tubes and half the number of holes in the bottom of the drum were plugged, together and separately, to determine the effect on the circulation, but no effect could be observed. The conclusion was that an unnecessary number of such tubes and openings are

used in this type of boiler and by reducing them the drum will be made a safer structure.

The quality of the steam was most satisfactory when water was carried at a proper level, and it was necessary to carry it near the top of the glass before the limit of a throttling calorimeter was reached.

TABLE I. DIMENSIONS OF BOILER

Width of casing at floor level	13 ft. 4 in.
Length of casing at floor level	7 ft. 10¼ in.
Height of center of drum above floor	11 ft. 8⅝ in.
Thickness of header plates	⅛ in.
Width of water spaces of headers	8 in.
Outside diameter of tubes	3 in.
Exposed length of tubes between headers	7 ft. 7½ in.
Number of tubes between headers	388
Number of tubes between rear header and drum	21
Inside diameter of drum	42 in.
Thickness of drum plates	⅝ in.
Width of furnace	12 ft.
Depth of furnace	6½ ft.
Height of furnace at center	3 ft. 8 in.
Firing doors	15 in. by 18 in.
Width of grate	11 ft. 11 in.
Depth of grate without bridge-wall	6 ft. 6 in.
Depth of grate with bridge-wall	5 ft. 8 in.
Grate area without bridge-wall	77½ sq. ft.
Grate area with bridge-wall	67½ sq. ft.
Heating surface fire sides	2518 sq. ft.
Thickness of brick lining	8½ in.

The Preliminary Tests

The preliminary tests to determine the best arrangement of baffles and distribution of air inlets consisted principally of a study of combustion by means of gas analyses and temperature readings. The gases were sampled with water-cooled sampling tubes and collected in glass holders over mercury. Each group of samples was collected simultaneously over a period varying from 15 to 40 minutes. The samples collected at the base of the stack were analyzed with the Orsat apparatus for CO_2, O_2 and CO. The gas samples taken in the furnace were analyzed by Hempel's method, for CO_2, O_2, CO, H_2, CH_4, and unsaturated hydrocarbons.

Fig. 2 is a diagram of the three-pass boiler as originally designed. After the first few tests the baffles were extended, making smaller gas passages between their ends and the water-legs. Other changes were also made as the investigation indicated the need for them. The points at which the gas samples were collected are indicated by the small circles designated by the capital letters *A* to *I*.

During the first six tests a large amount of combustible gas passed out of the furnace and either burned at the base of the stack or escaped unburned. It was apparent that not enough air was admitted over the fuel bed and that the air which was admitted was not sufficiently mixed with the gases to cause them to burn completely in the furnace. Some of the air admitted through the firing door found its way out of the furnace through the opening at *I*, between the first baffle and the front water-leg, as indicated by the arrow in Fig 2. A large part of the air also passed around the ends of the first baffle without mixing thoroughly with the combustible gases rising from the fuel bed. Evidently, the combustion

TABLE II. RESULTS OF EVAPORATIVE TESTS OF THREE-PASS BOILER EQUIPPED WITH WAGER BRIDGE-WALL AND HAND-FIRED

		June 12	June 13	June 14
1	Date, 1918	June 12	June 13	June 14
2	Duration, hours	10	10	10
	Dimensions and Proportions			
3	Grate area, sq.ft.	65.54	65.54	65.54
4	Heating surface, sq.ft.	2,500	2,500	2,500
5	Ratio heating surface to grate area	38.20	38.20	38.20
	Average Pressures			
6	Gage pressure, lb.	179	178	179
7	Atmospheric pressure, lb.	14.28	14.41	14.41
8	Absolute pressure, lb.	193.28	192.41	193.41
9	Draft between damper and boiler, in.	0.53	0.58	0.63
	Average Temperature			
10	External air, deg. F.	59	64	64
11	Fire room, deg. F.	74	77	70
12	Feed water, deg. F.	204	209	207
13	Escaping gases, deg. F.	538	543	551
	Fuel			
14	Moist coal consumed per hour, lb.	1,455	1,411	1,521
15	Moisture in coal, per cent	2.19	2.39	2.02
16	Dry coal per hour, lb.	1,423	1,380	1,490
17	Dry refuse per hour weight, lb.	151	143	159
18	Dry refuse per cent	10.60	10.35	10.65
19	Combustible per hour, lb.	1,272	1,237	1,331
	Quality of Steam			
20	Moisture in steam, per cent.	0.51	0.62	0.41
	Heat Value of Coal and Efficiency			
21	Heat value of a pound of dry coal, B.t.u.	14,380	14,396	14,350
22	Efficiency of boiler based on dry coal, per cent	70.30	71.50	70.80
23	Efficiency of boiler based on combustible, per cent	72.00	73.20	73.00
	Water			
24	Water supplied to boiler per hour, lb.	14,032	13,922	14,780
25	Dry steam generated, lb.	13,962	13,836	14,719
26	Factor of evaporation	1.057	1.052	1.054
27	Equivalent evaporation from and at 212 deg., lb.	14,758	14,555	15,514
	Evaporative Performance			
28	Water evaporated per pound of dry coal, lb.	9.81	10.05	9.90
29	Equivalent from and at 212 deg., lb.	10.36	10.56	10.42
30	Water evaporated per pound of combustible, lb.	10.95	11.22	11.05
31	Equivalent from and at 212 deg., lb.	11.56	11.78	11.68
	Rate of Combustion			
32	Dry coal burned per sq.ft. of grate per hour, lb.	21.80	21.10	22.80
33	Dry coal burned per sq.ft. heating surface per hour, lb.	0.57	0.55	0.60
	Rate of Evaporation			
34	Water evap. from and at 212 per sq.ft. h. s. per hour, lb.	5.90	5.80	6.20
35	Water evap. from and at 212 deg. per sq.ft. grate per hour, lb.	226	222	257
	Power of Boiler			
36	Commercial horsepower for land use	428	422	450
37	Excess above commercial rating of 250 hp., per cent	71	69	80
38	Marine rating, water evap. from and at 212 deg. per hour, lb.	15,000	15,000	15,000
39	Equivalent commercial horsepower of marine rating	435	435	435
40	Excess above or below marine rating, per cent	1.80 below	3.20 below	3.20 above

TABLE III. RESULTS OF EVAPORATIVE TESTS OF THREE-PASS BOILER EQUIPPED WITH WAGER BRIDGE-WALL AND HAND-FIRED

		June 17	June 18	June 19	June 20
1	Date, 1918	June 17	June 18	June 19	June 20
2	Duration, hours	10	10	10	10
	Dimensions and Proportions				
3	Grate area, sq.ft.	65.54	65.54	65.54	65.54
4	Heating surface, sq.ft.	2,500	2,500	2,500	2,500
5	Ratio grate area to heating surface.	....	....	....	....
	Average Pressures				
6	Gage pressure, lb.	175.00	178.00	182.10	180.30
7	Atmospheric pressure, lb.	14.49	14.54	14.56	14.53
8	Absolute pressure, lb.	189.49	192.54	196.66	194.83
9	Draft between damper and boiler, in.	0.64	0.64	0.61	0.39
	Average Temperatures				
10	External air, deg. F.	74	68	68	61
11	Fire room, deg. F.	83	80	80	69
12	Feed water, deg. F.	211	212	211	216
13	Escaping gases, deg. F.	538	531	556	510
	Fuel				
14	Moist coal consumed per hour, lb.	1,478	1,436	1,530	1,274
15	Moisture in coal, per cent	1.76	2.02	2.09	2.04
16	Dry coal consumed, per hour, lb.	1,450	1,406	1,498	1,248
17	Dry refuse per hour, lb.	152	138	132	109
18	Dry refuse in per cent	10.50	9.80	8.80	8.75
19	Combustible consumed per hour, lb.	1,298	1,268	1,366	1,139
	Quality of Steam				
20	Moisture in steam, per cent.	0.40	0.40	0.30	0.30
	Heat Value of Coal and Efficiency				
21	Heat value of one pound of dry coal, B.t.u.	14,409	14,237	14,441	14,251
22	Efficiency of boiler based on dry coal, per cent.	69.80	70.80	67.30	68.60
23	Efficiency of boiler based on combustible, per cent.	72.00	71.50	68.30	69.00
	Water				
24	Water supplied to boiler per hr., lb.	14,345	13,915	14,242	12,094
25	Dry steam generated per hour, lb.	14,284	13,859	14,196	12,056
26	Factor of evaporation	1.049	1.048	1.050	1.045
27	Equivalent evaporation from and at 212 deg. per hour, lb.	14,984	14,524	14,906	12,599
	Evaporative Performance				
28	Water evaporated per pound of dry coal, lb.	9.87	9.84	9.50	9.65
29	Equivalent from and at 212 deg., lb.	10.32	10.33	9.96	10.02
30	Water evaporated per pound of combustible, lb.	11.00	10.90	10.40	10.55
31	Equivalent from and at 212 deg., lb.	11.55	11.45	10.92	11.05
	Rate of Combustion				
32	Dry coal burned per sq.ft. of grate per hour, lb.	21.10	21.50	22.90	19.00
33	Dry coal burned per sq.ft. of heating surface per hour, lb.	0.58	0.56	0.60	0.50
	Rate of Evaporation				
34	Water evap. from and at 212 deg. per sq.ft. h.s. per hour, lb.	5.94	5.81	5.96	5.04
35	Water evap. from and at 212 deg. per sq.ft. grate per hour, lb.	229	222	228	192
	Power of Boiler				
36	Commercial horsepower for land use	434	421	432	365
37	Excess above commercial rating of 250 hp., per cent	74	68	73	46
38	Marine rating in water evap. per hour from and at 212 deg., lb.	15,000	15,000	15,000	15,000
39	Equivalent commercial horsepower of marine rating	435	435	435	435
40	Excess above or below marine rating, per cent	0.20 below	3.20 below	0.70 below	15 below

space was too small and the path of the gases and air through the furnace was too short for the two to form an intimate mixture.

It was apparent that more air had to be admitted over the fuel bed and better means provided for mixing it with the combustible. It is a proven fact that in a hand-fired furnace, when the fuel bed is level and five inches or more deep, no free oxygen can be forced through it, no matter what air pressure is used in the ashpit. It is true that if the fuel bed contains holes or thin spots, air passes through them. However, admission of air through holes in the fire is undesirable because the size of holes cannot be controlled. It is therefore much better to admit air over the fuel bed through special openings in the firing door or in the bridge-wall, as the quantity of air admitted through such openings can be very easily controlled. The air should be supplied in a large number of small jets and as close to the fuel bed as practicable, so that as much as possible of the combustion space above the fuel bed is utilized for mixing and combustion.

Following these principles a number of ½-in. holes were made in each firing door; the opening in the first baffle at *J* was closed and the baffle extended, making the gas passage between the end of the baffle and the rear water-leg 36 in. wide. This had the effect of causing the air admitted through the firing door to flow farther to the rear of the furnace and to facilitate better mixing with the combustible gases. In addition to these changes Wager's bridge-wall was installed, as shown in Fig. 3, to supply additional air to the rear part of the furnace. This bridge-wall consists of a large number of cast-iron bars placed in the rear wall of the furnace and forms a structure similar to a plain grate. The air passes into the furnace in a large number of thin streams through narrow slots between the bars.

With the air admitted through the firing door and through the bridge-wall, the combustible gases rising from the fuel bed are squeezed between two streams of air coming in from two different directions, and the mixing is greatly aided. The total area for admission of air over the fuel bed, including the openings in the fire-doors, the space between the door frames and the fire-doors and the space in the bridge-wall, was about 160 sq. in. This opening is approximately 2 per cent of the grate area.

The analyses of the gas samples taken from various parts of the furnace were studied to determine the effect of the different methods of admitting air. It was found that the use of the Wager bridge-wall provided the best condition for combustion, if too thick a fuel bed was not maintained next to the bridge-wall. If the fuel bed was too thick, it cut down the available area for admission of air over the fuel. In parts of these tests air was admitted through nozzles in the first baffle, as shown in Fig. 3. It was found in general that the admission of air through the bridge-wall under pressure proved to be undesirable in this type of furnace, and while the test using the nozzles proved satisfactory, the installation of these nozzles was omitted as entailing undesirable complications in boiler plants for ships.

TABLE IV. RESULTS OF EVAPORATIVE TESTS OF FOUR-PASS BOILER EQUIPPED WITH WAGER BRIDGE-WALL AND HAND-FIRED.

1	Date, 1918	Dec. 19	Dec. 16	Dec. 17	Dec. 18
2	Duration, hours	12.01	7.97	10.07	8.27
	Dimensions and Proportions				
3	Grate area, sq.ft.	66.53	66.53	66.53	66.53
4	Heating surface, sq.ft.	2,500	2,500	2,500	2,500
5	Ratio grate area to heating surface.	37.58	37.58	37.58	37.58
	Average Pressures				
6	Gage pressure, lb.	200.50	200.00	197.30	198.60
7	Atmospheric pressure, lb.	14.67	14.67	14.68	14.70
8	Absolute pressure, lb.	215.17	214.67	211.98	213.30
9	Draft between boiler and damper, in.	0.34	0.44	0.78	1.56
	Average Temperatures				
10	External air, deg. F.	49	37	38	41
11	Fire room, deg. F.	63	59	57	59
12	Feed water, deg. F.	207.80	184.50	206.00	198.90
13	Escaping gases, deg. F.	506	513	557	648
	Fuel				
14	Moist coal consumed per hour, lb.	1,032	1,149.70	1,443.70	1,934
15	Moisture in coal, per cent	1.49	2.15	1.54	1.91
16	Dry coal per hour, lb.	1,017	1,125	1,411.50	1,897
17	Dry refuse per hour weight, lb.	111	168	143.40	166.50
18	Dry refuse, per cent.	10.95	13.45	10.15	8.80
19	Combustible per hour, lb.	906	957	1,268.10	1,730.50
	Quality of Steam				
20	Moisture in steam, per cent.	0.61	1.07	0.62	0.54
	Heat Value of Coal and Efficiency				
21	Heat value of one pound of dry coal, B.t.u.	14,292	13,990	14,213	14,216
22	Efficiency of boiler based on dry coal, per cent	72.60	72.80	71.00	70.90
23	Efficiency of boiler based on combustible, per cent.	74.30	76.60	72.30	71.00
	Water				
24	Water supplied to boiler per hr., lb.	10,349	11,074	14,042	18,509
25	Dry steam generated per hour, lb.	10,286	10,956	13,955	18,409
26	Factor of evaporation.	1.053	1.077	1.055	1.073
27	Equivalent evaporation from and at 212 deg. per hour, lb.	10,831	11,800	14,723	19,753
	Evaporative Performance				
28	Water evaporated per pound of dry coal, lb.	10.10	9.73	9.90	9.75
29	Equivalent from and at 212 deg. lb.	10.70	10.50	10.46	10.40
30	Water evap. per lb. combustible, lb.	11.30	11.45	11.00	10.62
31	Equivalent from and at 212 deg. lb.	11.95	12.30	11.61	11.40
	Rate of Combustion				
32	Dry coal burned per sq.ft. grate per hour, lb.	15.30	16.90	21.30	28.60
33	Dry coal burned per sq.ft. heating surface per hour, lb.	0.41	0.45	0.57	0.76
	Rate of Evaporation				
34	Water evap. from and at 212 deg. per sq.ft. h. s. per hour, lb.	4.30	4.72	5.90	7.50
35	Water evap. from and at 212 deg. per sq.ft. grate per hour, lb.	163	177.50	222	297
	Power of Boiler				
36	Commercial horsepower for land use	314	342	427	573
37	Excess above commercial rating of 250 hp., per cent.	26	37	71	129
38	Marine rating in water evap. from and at 212 deg. per hour, lb.	15,000	15,000	15,000	15,000
39	Equivalent commercial horsepower marine rating	435	435	435	435
40	Excess above or below marine rating, per cent.	28 below	22 below	2 below	31 above

TABLE V. RESULTS OF EVAPORATIVE TESTS OF FOUR-PASS BOILER EQUIPPED WITH TWO TYPE "E" UNDERFEED STOKERS

1	Date, 1919	April 8	April 9	April 13	April 12
2	Duration, hours	24	24	24	24
	Dimensions and Proportions				
3	Grate area, sq.ft.	77.50	77.50	77.50	77.50
4	Heating surface, sq.ft.	2,500	2,500	2,500	2,500
5	Ratio grate area to heating surface.	32.26	32.26	32.26	32.26
	Average Pressures				
6	Gage pressure, lb.	199.00	199.00	197.00	198.40
7	Atmospheric pressure, lb.	14.51	14.51	14.50	14.44
8	Absolute pressure, lb.	213.51	213.51	211.50	212.84
9	Draft between damper and boiler, in.	0.35	0.85	1.40	1.43
	Average Temperatures				
10	External air, deg. F.	47	53	50	44
11	Fire room, deg. F.	61	68	63	62
12	Feed water, deg. F.	66	67	66	63.40
13	Escaping gases, deg. F.	535	591	618	659
	Fuel				
14	Moist coal consumed per hour, lb.	1,189	1,614	2,000	2,392
15	Moisture in coal, per cent.	2.92	2.82	3.35	4.14
16	Dry coal consumed per hour, lb.	1,155	1,568	1,933	2,293
17	Dry refuse per hour, lb.	126	160	184	214
18	Dry refuse in per cent.	10.90	10.20	9.50	9.30
19	Combustible consumed per hour, lb.	1,029	1,408	1,749	2,079
	Quality of Steam				
20	Moisture in steam, per cent.	0.75	0.75	0.85	1.02
	Heat Value of Coal and Efficiency				
21	Heat value of one pound of dry coal, B.t.u.	14,040	14,342	14,234	14,404
22	Efficiency of boiler based on dry coal, per cent.	79.20	75.00	72.50	71.40
23	Efficiency of boiler based on combustible, per cent.	80.20	76.50	72.90	72.50
	Water				
24	Water supplied to boiler per hour, lb.	11,124	14,588	17,253	20,390
25	Dry steam generated, per hour, lb.	11,041	14,479	17,106	20,182
26	Factor of evaporation.	1.20	1.20	1.20	1.204
27	Equivalent evaporation from and at 212 deg. per hour, lb.	13,249	17,375	20,527	24,299
	Evaporative Performance				
28	Water evaporated per pound of dry coal, lb.	9.55	9.23	8.87	8.80
29	Equivalent from and at 212 deg., lb.	11.47	11.08	10.62	10.60
30	Water evaporated per pound of combustible, lb.	10.85	10.21	9.80	9.66
31	Equivalent from and at 212 deg., lb.	12.90	12.34	11.70	11.68
	Rate of Combustion				
32	Dry coal burned per sq.ft. grate per hour, lb.	14.90	20.23	23.80	29.60
33	Dry coal burned per sq.ft. heating surface per hour, lb.	0.46	0.62	0.77	0.92
	Rate of Evaporation				
34	Water evap. from and at 212 deg. per sq.ft. h.s. per hour, lb.	5.30	6.95	8.21	9.72
35	Water evap. from and at 212 deg. per sq.ft. grate per hour, lb.	170.90	234.20	264.00	313.60
	Power of Boiler				
36	Commercial horsepower for land use	384	504	595	704
37	Excess above commercial rating of 250 hp., per cent.	54	102	138	182
38	Marine rating in water evap. per hour from and at 212 deg., lb.	15,000	15,000	15,000	15,000
39	Equiv. commercial hp. of marine rating	435	435	435	435
40	Excess above or below marine rating, per cent.	12 below	16 above	37 above	62 above

The temperatures were measured with thermocouples inserted in the setting through the hollow stay-bolts and moved across the gas passages, as indicated by the straight lines labeled couples, or *C*, in Figs. 2 and 3. These temperatures were measured across the space between the end of the baffles and the water-leg.

An analysis of the temperature readings at various points in the passage gave considerable information as to the flow of the gases. In the three-pass boiler there appeared no regular variation in temperature in the first pass. This indicates that the distribution of the hot gases through this pass is nearly uniform. The second pass, however, shows the highest temperature one foot from the end of the baffle and the temperature drops down rapidly on each side of this point. This seems to indicate that a large part of the hot gases had passed through the space between 6 in. and 24 in. from the end of the baffle. The remaining space of about 24 in. next to the front water-leg contains only slowly moving and comparatively cool gases.

The same condition exists in the third pass, most of the hot gases passing through the 18-in. space next to the end of the third baffle. These temperature measurements show the desirability of lengthening the second and third baffles and thus causing the hot gases to pass over the greater part of the heating surface of the boiler. Although the temperature measurements did not show the desirability of lengthening the first baffle, this baffle was made 10 in. longer after the first six tests, for the purpose of improving the mixing of the air and combustible gases rising from the fuel bed. The variation in temperature measurements showed the difficulty of measuring temperature with a single couple. Such measurements might easily be several hundred degrees higher or lower than the average temperature in the pass. In general the temperature measurements in the four-pass boilers indicated the same characteristics as were found in the three-pass boilers. These measurements showed the desirability of decreasing the area of the passages so that more heating surface might be available even though it caused a greater frictional resistance to the passage of the gases.

Oil Fuel Versus Coal

By David Moffat Myers

Oil is almost an ideal fuel. It is the most beautiful fuel from an engineering standpoint with the exception of natural gas. Like natural gas, its supply is distinctly limited. One estimate gives 20 to 25 years as the probable period that oil fuel will last. It should, therefore, be applied to very special uses where its natural characteristics are distinctly and specially in demand, as in naval and certain classes of marine practice and for special processes, etc. It should not be burned indiscriminately and wasted, as our present coal supply is, and has been for many years.

Under equally favorable conditions, it is true that a somewhat higher thermal efficiency can be obtained with oil than with stoker-fired soft coal. On the other hand, an oil fire may be flooded with a tremendous excess of air without indicating the fact to the operator, as a coal fire would under the same conditions. It is really easier to fail in the efficient operation of oil than with coal, so that in the long run, especially in small plants, it is quite possible that the efficiency with oil might run below that which would probably obtain with coal. In a recent examination of a plant there was found an extravagant waste of oil on account of the reasons just stated.

The labor of ash handling with oil burning is, of course, entirely eliminated. In the small plant, however, it would frequently be impossible actually to save any money, as the time of one man could not be eliminated even if ash handling had become unnecessary. In large plants, on the other hand, it is possible that a considerable labor saving can be made by the elimination of the handling of ash. For the sake of safety in any boiler plant at least two men should be on the job so that the apparent saving of labor does not always reflect itself in money saving.

*From paper presented at annual meeting of the American Society of Heating and Ventilating Engineers, New York, January, 1920.

Owing to the extremely small supply of oil as compared to coal, the former fuel should be used, as has been previously indicated, for special purposes which require its advantages, and it is evident that it should not be consumed wastefully. In the average office building not over 4 or 5 per cent of the heat energy in the fuel as fired is converted into electrical energy at the busbars. It seems a crime to consume so rare and valuable a fuel as oil with a heat loss of 25 per cent. It is bad enough to do this with cheaper coal of which there is an infinitely greater supply. Of course during the heating season, when possibly as high as 60 per cent of the original heat value of the fuel is rendered useful by the application of exhaust steam to heating and process, the case takes on a different aspect.

It is probable, however, that not much "discouraging" will be necessary. I recently endeavored to secure a supply of fuel oil for one of the legitimate cases, for a plant just outside New York City limits, and found it impossible to obtain a contract from any of the oil companies. These companies were unable to say how soon they would be able to make any further contracts and in any event did not wish to consider guaranteeing a supply for more than a three months' period. One stated they might, at some distant time, give a one-year contract.

We have recently been called to report on the oil and coal situation in a very large office-building plant in Philadelphia, which is to be constructed. Our findings may be briefly summarized as follows:

A. For the safe storage of oil an additional $60,000 would have to be spent, of which excavation alone would cost $25,000.

B. Owing to the uncertainty in supply, it would not be safe to equip such a building to depend on oil exclusively. Consequently, a coal-burning equipment would have to be installed in any event, and if oil were used it would be used only as an auxiliary fuel at such times when prices might favor its use.

C. No saving in operation at existing prices of oil and coal could be shown in favor of oil. In fact, the difference in operating cost favors coal.

This does not mean that there may not be a great many cases, as there undoubtedly are, where oil would be the more economical fuel to employ. In fact, we have recently reported in favor of oil for a certain industrial plant where a long contract for oil supply could be secured and where the labor situation was the deciding factor in the problem. In this plant, however, the exhaust steam was entirely utilized so that the over-all efficiency of the plant would be high and the oil would be economically applied.

Ball Bearings in Steamship Engine Construction

The Swedish ball-bearing manufacturers, after introducing successfully ball bearings in Swedish rolling stock, especially the Swedish State railways, are now entering new fields of experimentation, which have for their object the introduction of the ball-bearing principle in ship construction, especially in connection with propeller shafting. The problem comprises the construction of a bearing able to withstand all axial pressure from the propeller and excluding all possibilities of hot box and kindred troubles. The successful ball bearing, it is claimed, must under the most trying conditions be able to withstand the axial pressure automatically and require little or no attention and must be of such simple and reliable construction that friction within the same is minimal and that the ship's movements may not influence disadvantageously the ball-bearing mechanism.

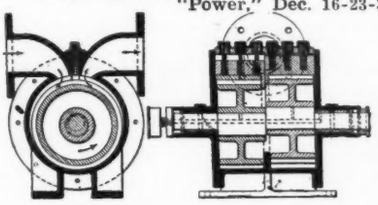
The bearings hitherto used have proved unsatisfactory in these respects, it is said.

While ball bearings are used to a considerable extent in marine engineering, their application and their mounting have seen their highest development in Swedish shipyards. This is the contention of Swedish shipbuilders generally, but will doubtless meet challenge in the United States and Great Britain, where shipbuilding yards have not been slow to see the advantages offered by the ball bearings in modern ship construction.—*Commerce Reports.*

Condensed-Clipping Index of Equipment

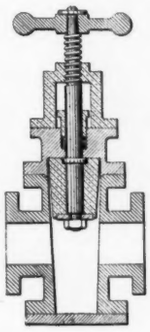
Clip, paste on 3 x 5-in. cards and file as desired

Pump, Squeegee Rotary
Avamore Engineering Co., Ltd., Queen Victoria Street, London, England.
"Power," Dec. 16-23-30, 1919



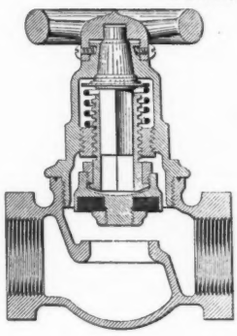
This pump consists of six main parts — the casing, two covers, shaft and two rotors, which in the standard design are covered with India rubber. The eccentrics, which are solid with the shaft and have only a small throw, impart movement to the rotors, which are a loose fit on the eccentrics. The displacement is caused by the rolling of the rotor when driven around by the eccentric on the main shaft. With the shaft rotating in an anti-clockwise direction, the rotor rolls around in the same direction, but on account of its being smaller in circumference than the track in the casing, it rotates in a clockwise direction in proportion to the difference between the circumference of the casing and that of the rotor. Small deflecting valves, one for each rotor, are placed in the upper portion of the casing, and are held in position against the rotor by small springs. The pumps are made in sizes from 1 to 4 in. diameter pipe connection, with a capacity of 700 gal. to 1,300 gal. per hour when run at 1,250 and 720 r.p.m. respectively.

Valve, Universal All-Service
Universal All-Service Valve Co., 12419 Lancelot Ave., Cleveland, Ohio.
"Power," Nov. 11-18, 1919



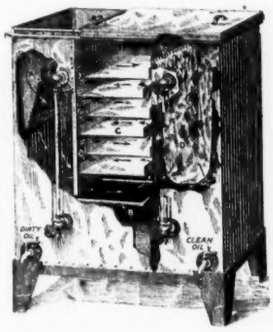
This valve is made so that it can be used as a straightway, three-way or angle valve by merely changing the position of a removable flange. The disk is round and taper-shaped and is removed from the action of the flow of liquid to the valve when in the open position. A pocket is found below the disk in which sediment is deposited and can be removed through a blowoff pipe or by removing the bottom flange. In large valves a by-pass is arranged, connecting with the valve body and the bottom flange, so that when the pressure is equalized, the pressure also exerts itself against the bottom of the flange of the disk and assists in opening it. The valve is adaptable for steam lines, blowoffs, etc.

Valve, Defiance Packless
Defiance Packless Valve Co., St. Louis, Mo.
"Power," Nov. 25, Dec. 2-9, 1919



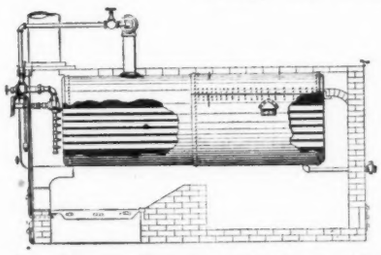
This valve is made with a metal-to-metal seat at the top of a nonrising stem. The one-piece bonnet is interchangeable with practically all valve bodies. No packing is employed. The stem acts as a key to raise and lower the valve disk. It is double-seated in the bonnet at angles of 10 and 30 deg., and is held against the seats by a spring. The valve stem is made square in cross-section, and of metal harder than the bonnet, to take care of expansion and contraction and to guard against cutting or grinding. Turning the handle will raise or lower the valve disk without imparting a similar movement to the stem.

Filter, Bowser Seven F
S. F. Bowser & Co., Inc., Fort Wayne, Ind.
"Power," Nov. 11-18, 1919



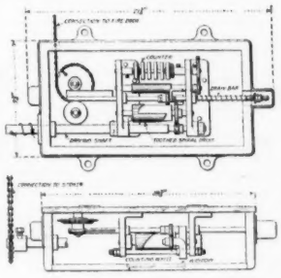
In this filter four operations are performed, in the order following: Screening, precipitation of water, precipitation of solids, and filtering and storing of the clarified oil. Foreign material in the oil is separated in a strainer, and the oil then passes down around the steam coils and up and around a precipitating tray, and then into a separate compartment into filtering bags, from which the oil runs to a storage base below.

Cleaner, Adriance-Bates Mechanical Flue
Adriance-Bates Steam Fuel Economy Corp., 80 Richards St., Brooklyn, N. Y.
"Power," Nov. 11-18, 1919



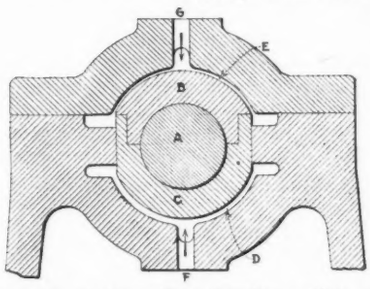
This cleaner has six nozzles, built so that each one blows an individual tube of the boiler on which it is installed. The steam blast is controlled by valves on the exterior of the boiler setting. Condensation is taken care of by a bleeder pipe. When in use, the pressure entering the tube passes through jets designed to create centrifugal force of great velocity. The cleaner does not interfere with the natural draft and is removable by disconnecting a ground joint. It requires less than three minutes to blow the tube of a boiler.

Meter, Boiler Coal
Lee Recorder Co., Ltd., 28 Deans Gate, Manchester, England
"Power," Sept. 16, 1919



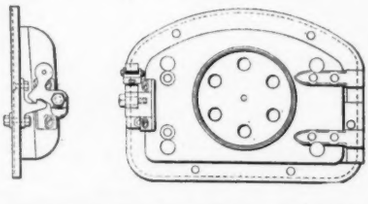
This device is especially intended for boilers operating with chain grates and works on same lines as the V-notch recorder and integrator for water measurements. The amount of coal passing under the fire-door is regarded as the flow, but the depth and velocity of the fuel are subject to variation. The reading is easily made, no skilled attention is required, and the makers give a guarantee of accuracy to within 5 per cent.

Bearings for High Speed Gears
British Westinghouse Electric & Mfg. Co., London, England.
"Power," Dec. 16-23-30, 1919



This bearing is supported in position by films of oil which are maintained by forcing the oil through one or more relatively small clearance spaces provided between the bearing and its support. The position of one bearing with respect to another may be adjusted by forcing a greater quantity of oil through the clearance space or spaces between the bearings and its support than through the clearance space or spaces of the other bearing. This adjustment may be made while the apparatus is in motion.

Latch, De Waters Safety
De Waters Safety Latch Co., Central Ave., Far Rockaway, N. Y.
"Power," Dec. 16-23-30, 1919



This latch is designed to prevent furnace doors from being forced open in case of ruptured boiler tubes. The latch cannot be lifted, except by external force applied to a weight, which always tends to force the latch nose down on the keeper. The latch is always in a position ready to lock. Its movement is limited by a double stop space to the amount required to clear the keeper. When released, it rests on a beveled stop face in a position to ride over the keeper when the door is closed. This latch is also applicable to elevators, fire-doors and other openings.

Patented Aug. 20, 1918

Four-Day Test on Five Oneida Street Boilers Burning Pulverized Coal

THE isometric sketch, Fig. 1, and the sectional view, Fig. 2, set forth the equipment used in the operation of the pulverized-fuel burning plant at the Oneida Street station. Screenings coal is delivered to the station by barge and run over an automatic scale, discharged onto a short belt conveyor equipped with a magnetic separator pulley for removal of trampiron and then into a bucket conveyor which carries it to the green-coal storage bunkers, the starting point as shown on the sketch. From there it is conveyed and elevated to a disintegrator, where it is prepared for drying by being crushed, discharged into a small storage bin and fed to the drier. The drier is of the double-shell type and is so arranged that the gases exhausted from it are discharged through a cyclone separator where coal dust, carried from the shell, is reclaimed and conveyed to the pulverizers. The gases discharged from the separator are vented into the smokestack. The dried coal is carried from the drier discharge by

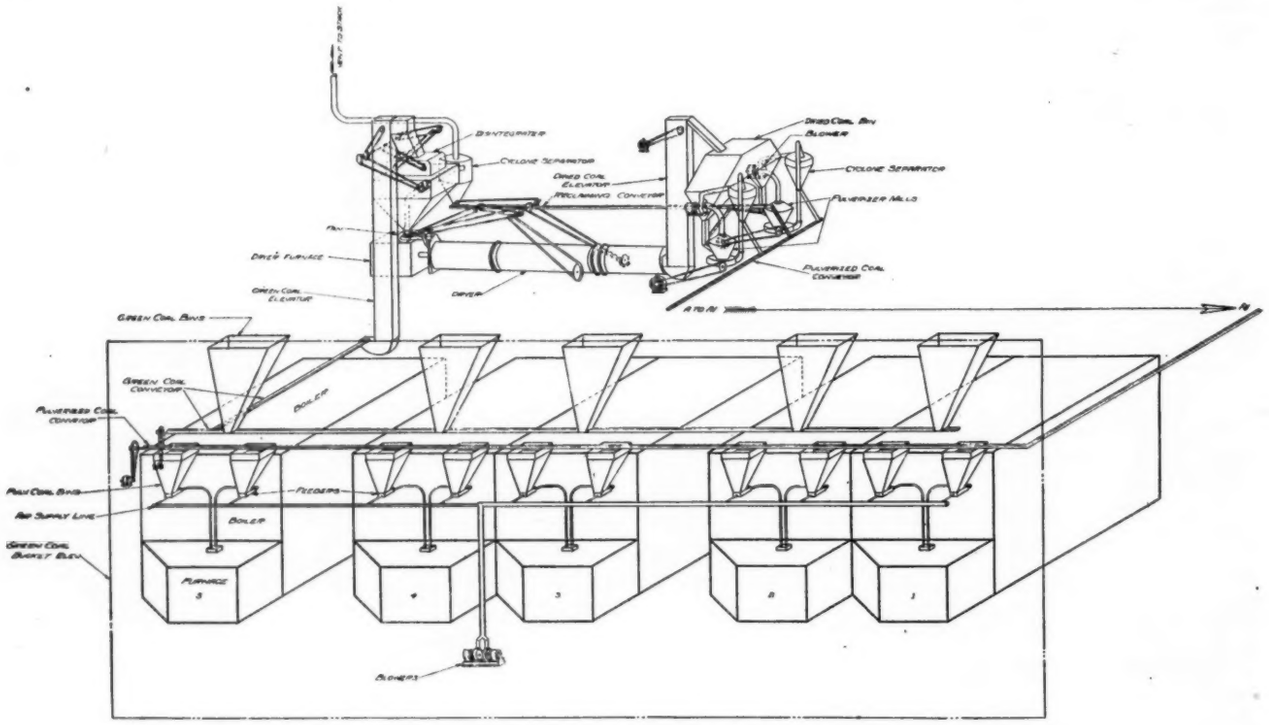


FIG. 1. LAYOUT OF PULVERIZED- FUEL PLANT AT ONEIDA STREET STATION

a bucket-elevator to the dry-coal storage bins, to which are connected the pulverizer feeders. The pulverizers are of the five-roll type. Pulverized coal from the mill outlets is conveyed by screw conveyors to the pulverized-fuel storage bins. Screw feeders take the fuel to the air-mixing chamber from where it is blown to the furnaces.

To obtain complete data on the pulverized-fuel installation for the purpose of making comparison with the stoker installation, no attempt was made to establish boiler-room conditions other than those maintained during regular operation.

To insure against any breakdowns during the test, the physical condition of the plant was carefully checked over, repairs being made wherever considered necessary. Boiler settings were examined and made airtight and all heat-radiating surfaces were properly insulated.

All necessary precautions against water leakage, from or to the boiler, were taken. Blowoff lines were disconnected and blanked. Water-column connections were broken and all regular feed lines to the boilers were disconnected and blanked.

All instruments were carefully calibrated and set, and arrangements for frequent checks were made wherever possible. Preliminary tests were made on the various parts of the system so as to insure proper operating conditions during the final test. A 24-hour preliminary test was conducted on the entire plant for the purpose of training the personnel as well as that of trying out the test equipment.

Apparatus and Instruments

The coal was weighed on an Avery scale, the automatic devices of which had been disconnected, making a hand scale, with dead weight on one side of the fulcrum and coal on the other. The capacity was 3,000 lb. per dump. The scale was checked at regular intervals, not more than 120 tons being weighed between calibrations. The accuracy was tested with 3,000 lb. in the form of 50-lb. standard scale blocks.

Four 2,000-lb. capacity tanks placed on platform scales were used for weighing water, these being mounted so as to empty into a receiving reservoir below, which was connected to the feed pump. The scales were balanced and checked at regular intervals.

Slag, ash and refuse were weighed on an ordinary platform scale. An aneroid barometer was used for the determination of atmospheric pressures. For obtaining flame temperatures, an optical pyrometer was used. Stack and steam temperatures were recorded by instruments. For all other temperature determinations mercury indicating thermometers were used. Drafts were read from liquid gages of the U-tube and multiplying types. For determination of the composition of flue gases, Orsat instruments were used. Solutions in these were renewed daily. A recording machine was also connected and used for comparison. Electrical data were obtained from integrating watt-hour meters. All pressure gages were set from a calibrated standard test gage, with proper allowances for water columns.

All data were recorded on prepared forms. Instrument readings were taken at regular intervals, varying from fifteen-minute periods on some instruments to one-hour periods on

others. Wherever possible automatic counters were used to check tallies made by operators. In other instances a double tally was made, each independent of the other. Data were so arranged that approximate checks could be made after the burning of each 40.5 tons of coal. Hourly checks were made on the water in order to maintain a uniform rating.

Kind of Coal Used in the Test

With the exception of the first day, when 100 per cent Youghiogheny was used, the coal for the test was a mixture 50 per cent each Eastern Kentucky and Youghiogheny screenings, running approximately 25 per cent nut, 45 per cent pea and 30 per cent slack. This coal is the same as is used in daily operation. The coal as supplied to the drier after passing through the disintegrator was approximately 50 per cent slack and 50 per cent small pea and nut, not any of the pieces being larger than ½ inch.

During the progress of the test the coal was regularly sampled at five points along the line of fuel travel. Samples taken at the coal scale were for moisture, proximate and ultimate analyses, while those taken at the drier inlet and outlet, and burner outlets were for moisture determinations only. All pulverizer outlets, and burner outlets were for moisture determinations only. All samples were taken and made up according to the A. S. M. E. standards. All determinations and analyses were made at the laboratories of the company, according to approved practices of the Bureau of Mines. An Emerson Bomb was used for obtaining caloric values of the coal.

In pulverized-fuel test practice standard methods cannot be followed. The levels of pulverized fuel in the storage bins is the determining factor in starting, checking and stopping.

Previous to the starting signal for the final test the green-coal system was run clean of fuel and the pulverized-fuel system filled to capacity. The conditions of the respective systems were identical for each check (after the burning of 40.5 tons of coal) and at the close of the test. The amount of coal to be burned between checks was determined by the capacity of the green-coal storage bunkers. Three bunkers of 40.5 tons capacity each were available during the test, all of which were filled once in twenty-four hours.

Operating Conditions

Operation in the pulverizing room was changed somewhat during the test in order to fulfill conditions required in making the periodic checks of boiler operation. It was essential that the levels of the fuel in the pulverized bins should be controllable at certain hours of the day (at the time of check) and therefore operation of pulverizer equipment was extended over twenty-four hours, although, without these considerations, sufficient coal could have been pulverized during an eighteen-hour run. As a result, irregular operation of the equipment—frequent starts and short runs—increased power consumption and decreased hourly capacities.

No interruptions due to failure of equipment occurred during the test. The pulverized-fuel conveyor choked up on two occasions when the storage bins were allowed to overfill at a check hour. Uniform and satisfactory removal of moisture was affected by the drier without any unusual regulation. The firing of the furnace was varied, as it is ordinarily, depending upon the moisture content of the green coal. The pulverizers operated uninterruptedly and provided fuel of the desired fineness with little variation.

During the first twenty-four hours of the test, it appeared that moisture, with its attendant difficulties, was collecting in the storage binds. Cold-air drafts through windows along the side of the bins caused this condition by rapidly condensing the vapor in the entrained air. When the windows were tightly closed, it was eliminated.

Choking and plugging of the screw feeders and feeder pipes were the chief causes of interruption in the fire room. It was on the second day that the tendency of the feeder lines to choke was most noticeable, and this must be attributed to the moisture conditions encountered the night previous. In one instance, however, one of the lines to a burner stopped feeding when a piece of tarred paper lodged in it above the burner. No doubt this had been dropped into the pulverized-fuel system accidentally. Operation of the furnace on which this occurred had been noticeably affected during the twenty-four hours previous to the removal of the pipe and the discovery of the source of trouble. A total of four feeder hours were lost during the test.

A high percentage of CO_2 was easily obtainable, but could not be maintained for longer than an hour at a time, owing to excessive slagging on the hearth. This slagging on the hearth and furnace bottoms may be attributed to flame characteristics resulting from certain draft conditions and can be avoided only by air regulation. On the newer type of Lopulco furnaces, such as are in use at the Oneida Street plant, the method of air regulation is such that while admitting air for slag prevention, a large volume not needed for combustion, enters, bypasses the flame zone and is carried with the products of combustion in the form of excess air. The high percentage of excess air, together with a correspondingly low percentage of CO_2, as indicated by the flue-gas analysis, was not determined by combustion considerations but rather by furnace limitations.

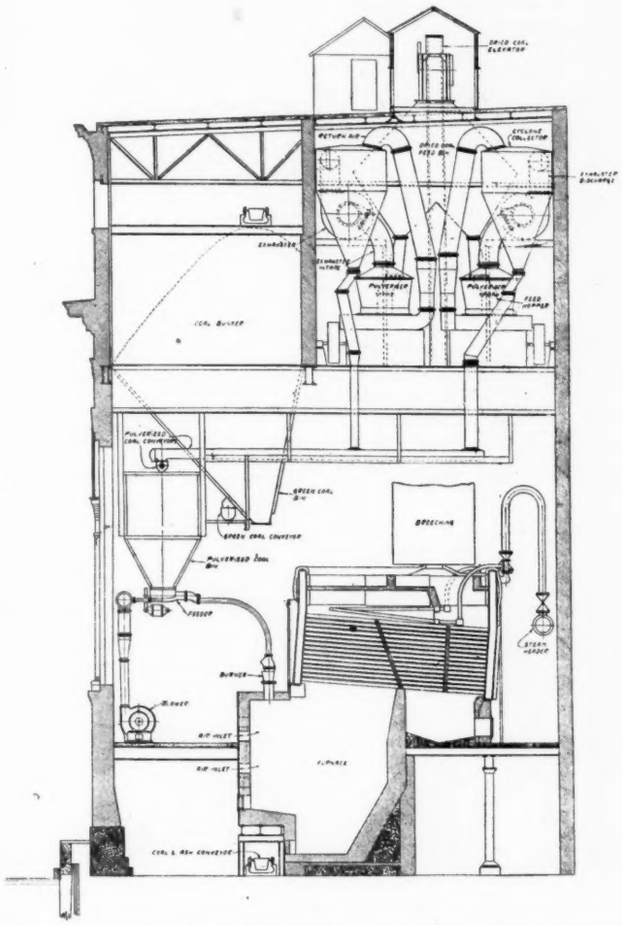


FIG. 2. TRANSVERSE SECTION THROUGH ONEIDA STREET BOILER PLANT

No slagging occurred on the boiler tubes. Flues were blown once every eight hours. Slag was withdrawn from the furnaces twice in twenty-four hours. Back-chamber ash was removed once every two days.

Owing to the use of a single stack for the entire boiler plant, which includes six underfeed-stoker boilers, no smoke observations were made. Smoke from the pulverized-coal furnaces, however, has proved on all occasions when pulverized fuel alone is used, to be of a negligible quantity and appears in the form of a light yellow haze, which disappears within 25 yards of the stack. The ash particles are so fine that no estimate can be made of the distance they are carried before being dropped from the air. No noticeable deposit has accumulated on or about the plant, although continuous operation has been carried on for more than a year.

TABLE I. TEST OF FIVE 468-HP. BOILERS
November 11-15, 1919

	Dimensions	
1.	Number and kind of boilers	Five Edge Moor water-tube boilers
2.	Kind of furnaces	Pulverized Fuel Equipment Corporation
3.	Volume of combustion space, per boiler, cu. ft	1678
4.	Water heating surface, sq.ft., per boiler	4680
5.	Superheating surface, sq.ft. per boiler (approximate)	594
	(a) Type of superheater	Foster
6.	Total heating surface, sq.ft., per boiler	5274
	(a) Ratio of water heating surface to volume of combustion space	1 to 0.359
	(b) Ratio of total heating surface to volume of combustion space	1 to 0.318
	Date, Duration, Etc.	
7.	Date	November 11-15, 1919
8.	Duration, hours	99
	(a) Boiler, hours	495
9.	Kind and size of coal	Mixture—50 per cent Yough. Scrgs. 50 per cent Eastern Kentucky Screenings.
	Average Pressures, Temperatures, Etc.	
10.	Steam pressure by gage, lb. per sq. in.	167.8
	(a) Barometric pressure, in. of mercury	29.49
11.	Steam pressure, absolute, lb. per sq.in.	182.3
12.	Temperature of steam leaving superheaters, deg. F.	441.9
	(a) Normal temp. sat. steam at above pres., deg. F.	374.2
13.	Temperature of feed water entering boiler, deg. F.	156.3
14.	Temperature of escaping gases, deg. F.	496.6
	(a) Temperature of flame above hearth, deg. F.	2,767
	(b) Temperature of furnace bottoms, deg. F.	2,180
15.	Draft under damper, inches of water	0.173
16.	Draft in furnaces, inches of water	0.031
17.	Air pressure at blower, inches of water	6.36
	(a) Pressure of air mixing with coal at screw feeder, inches of water	6.00
	(b) Pressure of air and coal mixture above burner outlet, inches of water	1.00
18.	State of weather.	
	(a) Temperature outside, deg. F	28.
	(b) Relative humidity, per cent	72.
	(c) Room temperature, deg. F	75.7
19.	Number of degrees of superheat	67.7
	Total Quantities	
20.	Total weight of coal, as received, pounds	958,074
21.	Percentage of moisture	7.23
22.	Total weight of coal, as fired, pounds	894,800
23.	Percentage of moisture	0.67
24.	Total weight of dry coal, pounds	888,805
25.	Slag, ash and refuse (dry, laboratory basis) per cent	11.90
	(A) Withdrawn from furnace bottom, pounds total	9,770
	(a) Withdrawn from furnace bottom, pounds per hour per boiler	19.8
	(B) Withdrawn from tubes, flues and combustion chamber, pounds total	9,862
	(b) Withdrawn from tubes, flues and combustion chamber, pounds per hour, per boiler	20.0
	(C) Blown away with gases, pounds (difference between laboratory and actual weighed)	87,549
	(c) Blown away with gases, pounds per hour per boiler	176.8
	(D) Percentage of total lost with gases	82.8
	(E) Percentage of combustible in slag and ash recovered, per cent (combined analysis)	6.9
26.	Total combustible burned, pounds	781,622
27.	Total weight of water fed to boilers	8,249,536
28.	Factor of evaporation	1.1473
29.	Total equiv. evap. f. and a. 212 deg. F., lb.	9,464,693
	Hourly Quantities and Rates	
30.	Dry coal per hour, pounds	8,978
	(a) Dry coal per hour, per boiler, lb.	1,796
31.	Water evap. per hour, lb. actual	83,328
	(a) Water evap. per hour, per boiler, lb. actual	16,666
32.	Equiv. evap. per hour f. and a. 212 deg. F., lb.	95,603
	(a) Equiv. evap. per hour, per boiler, f. and a. 212 deg. F., lb.	19,121
33.	Equiv. evap. per hour, f. and a. 212 deg. F., per sq.ft. of water heating surface, lb.	4.09
	Capacity	
34.	Evap. per hour, f. and a. 212 deg. F., per boiler, lb.	19,121
	(a) Boiler horsepower developed	554
35.	Rated cap. per hr. f. and a. 212 deg. F., per boiler, lb.	16,146
	(a) Rated boiler horsepower	468
36.	Percentage of rated capacity developed	118.4
	Economy	
37.	Water fed per lb. of coal, as received, lb.	8.611
38.	Water fed per lb. of coal, as fired, lb.	9.219
39.	Water evap. per lb. of coal dry, lb.	9.282
40.	Water evap. per lb. of combustible, lb.	10.554
41.	Equiv. evap. f. and a. 212 deg. F., per lb. of coal, as received, lb.	9.879
42.	Equiv. evap. f. and a. 212 deg. F., per lb. of coal, as fired, lb.	10.577
43.	Equiv. evap. f. and a. 212 deg. F., per lb. of coal dry, lb.	10.649
44.	Equiv. evap. f. and a. 212 deg. F., per lb. of combustible, lb.	12.109
	Gross Efficiencies	
45.	Calorific value of 1 lb. of dry coal by calorimeter, B.t.u.	12,810
46.	Gross Efficiency of boiler and furnace, per cent	80.67
47.	Efficiency of furnace, per cent	99.79
48.	Smoke data	See notes
	Analyses of Flue Gases	
49.	Carbon dioxide, per cent	12.26
50.	Oxygen, per cent	6.82
51.	Carbon monoxide, per cent	0.00
	Analyses of Coal	

52. Proximate.	As Received	As Fired	Dry
(a) Moisture	7.23	0.67	.....
(b) Volatile	32.13	34.40	34.63
(c) Fixed Carbon	49.60	53.11	53.47
(d) Ash	11.04	11.82	11.90
	100.00	100.00	100.00
(e) Sulphur separately determined referred to dry coal			1.62

53. Ultimate Analyses.	
(a) Carbon	73.57
(b) Hydrogen	4.35
(c) Oxygen	7.22
(d) Nitrogen	1.34
(e) Sulphur	1.62
(f) Ash	11.90
	100.00

54. Analyses of—

	Slag	Combustion Ash Retained	Combustion Ash Lost
(a) Moisture	0.00	13.00	
(b) Combustible	0.59	13.76	Unknown
(c) Earthy matter	99.41	86.24	

Heat Balance

	A.S.M.E. Method		Uehling Method	
	B.t.u.	Per Cent.	B.t.u.	Per Cent.
(a) Heat abs. by boiler	10334	80.67	10334	80.67
(b) Loss due to evap. of moisture in coal	8	0.06	8	0.06
(c) Loss due to heat carried away by steam formed by the burning of hydrogen	486	3.79	463	3.61
(d) Loss due to heat carried away in dry flue gases	1527	11.93	1551	12.11
(e) Loss due to carbon monoxide	0	0.00	0	0.00
(f) Loss due to combustible in ash	23	0.18	23	0.18
(g) Loss due to heating moisture in air	39	0.30	39	0.30
(h) Loss due to combustible carried away with flue gases, unconsumed hydrogen, hydrocarbons, radiation and unaccounted for	393	3.07	393	3.07
(i) Total calorific value of 1 lb. of dry coal	12810	.....	12810	.....
(j) Total per cent	.....	100.00	.....	100.00

Analyses of Losses

Losses due to the evaporation of moisture in coal, when expressed in a heat balance, are dependent upon the quantity of moisture in the coal as fired, and ordinarily are independent of installation. Since in this case, the coal was dried to 0.67 of 1 per cent of moisture, only a small loss, 0.06 of 1 per cent. due to the presence of moisture, occurred in combustion. The actual loss resulting from this factor is set forth in the table showing net boiler efficiency. It exceeds the minimum theoretical loss, dependent upon quantity of moisture that is always assumed in a heat balance and which in this case would be (if coal had not been dried) equal to 0.6 per cent. The efficiency of the drier referred to this basis is but 40 per cent.

Losses due to hydrogen in the coal are independent of the installation. In view of the fact that the boilers were operated at the most economical rating, losses due to heat carried away in the dry flue gases were higher than expected. To account for them, it must be considered that up to the time of the test three of the five boilers had been operated about 300 hours since receiving a partial wash, and that each of the five had been in service 600 hours since the last full cleaning. This condition, together with the fact that 90 per cent of the feed water was untreated reduced the heat absorption of the boilers appreciably. One of the boilers examined subsequent to the test showed scale deposits sufficient to affect efficiency.

Further losses under this heading may be attributed to an excess of air, not needed for proper combustion, but essential to the control of furnace temperatures and the prevention of excessive slagging on the hearth and furnace bottoms.

Losses due to carbon monoxide were not measurable, since but few analyses showed CO present, and then only in traces.

The loss due to combustible in the ash is very small and denotes the completeness of combustion. Since but 17.2 per cent of the total ash (laboratory basis) was recovered and half of that—the slag—contained no combustible, it might be assumed that, with the 82.8 per cent of ash that escaped with the flue gases, a large amount of combustible was carried away. On the other hand, it is more likely that since the unaccounted for losses are less than in the average boiler test, most of the unburned combustible lodged in the combustion chamber, and was without doubt the heavier particles.

Losses due to evaporation of moisture in the air are independent of the installation. The losses due to combustible carried away with the flue gases, unconsumed hydrogen, hydro-

carbons, radiation and unaccounted for losses are not great comparatively, and are not wholly preventable. Radiation was reduced to a minimum by properly covering and lagging the boilers.

Analyses of Coal During Test

In twelve proximate analyses of the coal made during the test, the moisture averaged 7.23 per cent in the coal as received at the plant. In the dry coal the following averages were obtained: Fixed carbon, 53.47; volatile matter, 34.63;

TABLE II TEST ON FUEL PULVERIZING EQUIPMENT

November 11-15, 1919

	Average Temperatures			
1	Temp. of air entering drier furnace, deg. F			93.8
2	Temp. of gases leaving drier, deg. F			181.8
3	Humidity of outside air, per cent			72.0
4	Draft through drier, in. of water			0.77
		No. 1	No. 2	
5	Vacuum in pulverizers, in. of water	5.0	5.16 Av.	5.08
	Coal Temperatures, Moistures and Fineness			
6	Temp. of coal entering drier, deg. F			88.2
7	Temp. of coal leaving drier, deg. F			237.9
8	Temp. of coal leaving pulverizers, deg. F			169.7
9	Moisture of coal entering drier, per cent			5.59
10	Moisture of coal leaving drier, per cent			1.61
11	Moisture of coal leaving pulverizers, per cent			1.03
12	Fineness of pulverized coal, 200 mesh, per cent			81.30
13	Fineness of pulverized coal, 100 mesh, per cent			97.40
14	Fineness of pulverized coal, 80 mesh, per cent			99.30
15	Fineness of pulverized coal, 60 mesh, per cent			100.00
	Total and Hourly Quantities			
16	Total coal crushed, as received at crusher, tons			479.0
17	Coal crushed per hour, as received, tons			17.5
18	Total coal dried, as received at drier, tons			471.2
19	Total coal dried per hour of drier operation, as received, tons			6.7
20	Total coal pulverized, coal from drier, tons			447.4
21	Capacity of pulverizer per hour, tons			5.0
22	Coal pulverized per hour, dry, tons total			7.90
23	Coal pulverized per hour, dry, tons per mill			3.95
24	Coal pulverized per hour, per mill, as received at plant, tons			4.23
	Consumption of Lubricants			
24	Total grease consumed by elevators and conveyors, lb			6.0
25	Grease per ton of coal, as received, lb			0.012
26	Total grease consumed by pulverizers, lb			13.0
27	Grease consumed per pulverizer per hour of operation, lb			0.112
28	Grease consumed per pulverizer per ton of coal pulverized, lb			0.028
29	Grease consumed on all equipment per ton of coal, as received, lb			0.040
30	Total oil consumed on all equipment, quarts			17.0
31	Oil consumed per ton of coal as received, quarts			0.036
	Electric Energy and Coal Consumption			
32	Total energy consumed by crusher and green coal elevator, kw.-hr.			220.0
33	Energy per ton of coal, as received, kw.-hr			0.47
34	Total energy consumed by drier, kw.-hr			735
35	Energy per ton of coal, as received, consumed by drier			1.53
36	Total energy consumed by pulverizers, kw.-hr. (fan and drive motor)			8010
		Mill No. 1	Mill No. 2	
37	Motor input per hour, hp	93.8		90.2
38	Energy consumed by pulverizer per ton of coal, as received kw.-hr.			16.72
39	Energy consumed by pulverizer per ton of coal, as pulverized, kw.-hr.			17.90
40	Total energy consumed by pulverized coal conveyors, feeder blowers and feeders			1789
41	Total energy consumed by pulverized coal conveyors, feeder blowers and feeders per ton of coal as received			3.73
42	Total energy consumed by pulverized coal conveyors, feeder blowers and feeders per ton of coal as fired			4.00
43	Total energy consumed by all equipment on preparation and firing of pulverized fuel, kw.-hr			10754
44	Energy per ton of coal, as received, kw.-hr.—grand total			22.45
45	Coal equivalent for this energy at 1.5 lb. coal per kw.-hr., lb.			33.68
46	Total coal used in drier furnace			12291
47	Coal per ton of fuel dried, lb. (based on coal as received)			25.66
48	Total coal and equivalent consumed in preparation and firing of one ton of pulverized fuel, lb			59.34
	Cost of Preparation—Operation and Maintenance			
49	Cost of labor per ton of coal—operation			$ 0.143
50	Cost of fuel for drying plus fuel for electric energy—coal at $4 per ton			0.119
51	Cost of lubricants per ton of coal—grease at 9c per lb			0.007
52	Cost of labor per ton of coal—maintenance			0.036
53	Cost of material—maintenance			0.020
54	Total cost per ton of coal			0.325

Note: Item 49 is based on the labor required to pulverize coal sufficient for five boilers through a twenty-four hour run per day.

ash, 11.90. In the coal as received the B.t.u. per pound averaged 11,884 and in the dry coal, 12,810. The average of four ultimate analyses of dry coal showed 73.57 per cent carbon, 4.35 per cent hydrogen, 7.22 per cent oxygen, 1.34 per cent nitrogen, 1.62 per cent sulphur and 11.90 per cent ash.

From an average of twelve tests the per cent of moisture in the coal at various points along the line of fuel travel was as follows: As received at the plant, 7.23; at the drier inlet, 5.59; at the drier outlet, 1.61; at the pulverizer outlet, 1.03; in the coal at the burners, 0.67. The fineness of the coal averaged through a 200-mesh screen, 81.3 per cent; through a 100 mesh screen, 97.4 per cent; through an 80-mesh screen, 99.3 per cent, and through a 60-mesh screen, 100 per cent.

TABLE III. SUMMARY OF RESULTS

	Electric Energy and Fuel Consumption Per Ton of Coal Pulverized	
1.	Energy consumed by conveyors, crushers, elevators, drier, blowers and feeders, kw.-hr	5.73
2.	Energy consumed by pulverizer, kw.-hr	16.72
3.	Total energy, kw.-hr	22.45
4.	Coal equivalent at 1.5 lb. per kw.-hr., lb	33.68
5.	Coal consumed in drier furnace, lb. per ton of fuel dried	25.66
6.	Total coal and equivalent, lb	59.34
7.	Gross efficiency less deductions for total coal and equivalent —Item 6	78.36
	Cost of Fuel Preparation, Firing and Ash Disposal	
8.	Labor—Coal preparation	$ 0.143
9.	Labor—Firing	0.112
10.	Labor—Ash removal	0.025
11.	Drier fuel—Coal at $4 per ton	0.051
12.	Electric energy—Coal per kw.-hr. at 1.5 lb	0.068
13.	Maintenance (Labor at 3.6c, material at 2c, manufacturers' estimate, lubricants at 0.7c)	0.063
14.	Total cost of fuel preparation, firing, ash disposal and maintenance	0.462
15.	Price of coal as purchased, per ton	4.000
16.	Total cost	4.462
	Efficiencies	
17.	Actual gross efficiency, per cent	80.67
18.	Net efficiency after all incidental costs have been accounted for, per cent	72.32

Conclusions can be best drawn from a comparison between pulverized-fuel burning equipment and mechanical stokers such as is given in Table IV.

TABLE IV. COMPARATIVE RESULTS WITH PULVERIZED FUEL AND UNDERFEED STOKER PER TON OF COAL BURNED

	Pulv. Fuel System	Modern Stoker
Energy consumed by conveyors, crusher, elevators, driers, fans and feeders, kw.-hr	5.73	10.94
Energy consumed by pulverizer, kw.-hr	16.72	.....
Total energy, kw.-hr	22.45	10.94
Coal equiv. at 1.5 lb. per kw.-hr., lb	33.68	16.41
Coal consumed in drier furnace, lb	25.66	.....
Total coal and equivalent, lb	59.34	16.41
Cost of Fuel Preparation, Firing and Ash Disposal		
Labor—coal preparation	$0.143	$0.000
Labor—firing	0.112	0.140
Labor—ash removal (in plant)	0.025	0.064
Drier fuel—coal at $4 per ton	0.051	0.000
Electric energy—coal per kw.-hr. at 1.5 lb	0.068	0.033
Maintenance:		
Labor at $0.036—material at $0.020, manufacturer's estimate—lubricants at $0.007	$0.063	Labor at $0.046, material at $0.049, lubricants at $0.002 $0.097
Total cost of fuel preparation, firing, ash disposal and maintenance	$0.462	$0.334
Price of coal as purchased per ton	4.000	4.000
Total cost per ton	4.462	4.334
Cost per ton of coal in P.F. system over modern stoker	0.128	.....
Efficiency		
Actual gross efficiency, per cent	80.67	76.80
Net efficiency after all incidental costs have been accounted for, per cent	72.32	70.88
Difference in favor of pulverized fuel system, per cent	1.44	.....

The tests were conducted by the engineers of the Milwaukee Electric Railway and Light Co., being directly supervised by Fred Dornbrook, chief engineer of the Commerce Street station, assisted by Messrs. Schubert and Mistele, test engineers. Paul W. Thompson, technical engineer of power plants, Detroit Edison Co., was present throughout the four days as an observer. The test was approved by John Anderson, chief engineer of power plants, for the company.

The expenditure which it is proposed to make on the development of the water power of the St. Lawrence is $26,000,000, while the output, it is said, will be 1,000,000 hp. The 80,000 hp. made available by the closing of the munition factories has already been used up, and there are applications for 110,000 hp., which cannot be supplied.

Trade Unionism in the Engineering Profession

On Feb. 24 the Milwaukee Chapter of the American Association of Engineers held an interesting meeting devoted to trade unionism in the profession. Dr. Isham Randolph and C. E. Dreyer, national secretary of the association, and A. E. Holcomb, president of the Milwaukee Chapter, addressed the gathering, consisting of some five hundred local engineers and architects. In reviewing the past and picturing the future of the engineer, Dr. Randolph expressed the firm belief that the engineer would win by hard work and by abiding by principles—not force. He urged the adoption of the Jones-Reavis bill. According to Secretary Dreyer, the unions and the American Association of Engineers have only one thing in common, and that is to improve economic conditions of their members. Violence and waste of strikes was a thing of horror to the engineers. In contradistinction from the unions the association is an incorporated organization responsible for its acts. On this question the attitude of the association is more fully expressed in the following printed statement used in circularizing the meeting.

"The engineer is the medium through which both capital and labor are used in production and in industrial development. The aim of the profession is to advance civilization and render the highest service to society. Except when their acts further this aim, it is an advocate of neither capital nor labor.

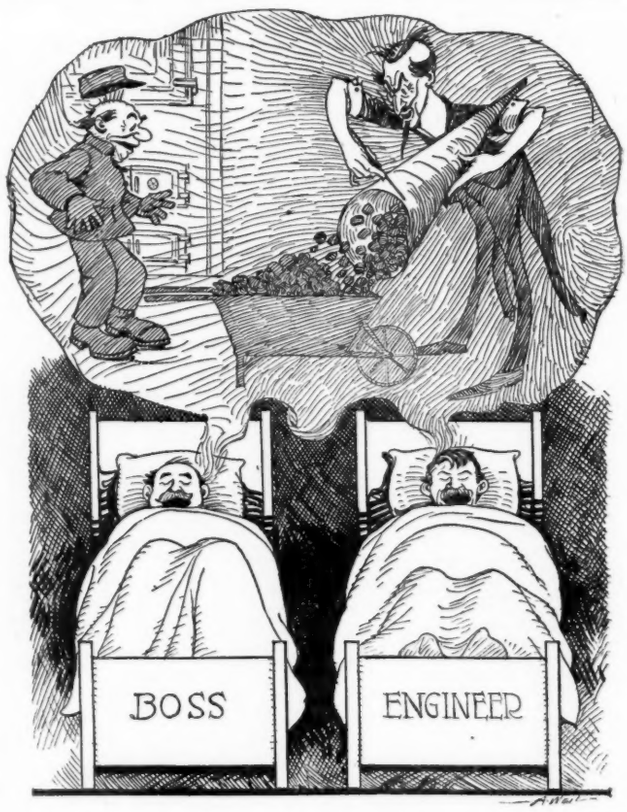
"Production should be increased—not limited. The profession cannot support strikes or lockouts or any other methods that may benefit any class at the expense of the nation as a whole. They are unsound and must inevitably lead to economic disaster. The law of supply and demand for men or material must ultimately prevail. Attempts may be made to limit the supply of either, but looking toward the upbuilding of civilization we believe rather in increasing the demand through the promotion of legitimate enterprises.

"Rewards should be according to ability, initiative and constructive effort. Men are not equal in these respects. Each man should be encouraged to do his utmost and be given compensation according to ability and will to increase production and to achieve large results.

"The engineer, as an educated professional man, believes in basing his claims for proper and just reward for his services upon the justice of the facts presented, upon enlightenment of public opinion, upon loyalty between employer and employee, and upon the underlying fundamental desire of the great majority to do what is fair and right when the merits of the case in question are clearly presented and demonstrated. We believe in organized representation for the correction of wrong, the advancement of the profession and service to the public but are opposed to methods inconsistent with the dignity of the profession which would lessen public confidence."

In his concluding remarks Mr. Dreyer told of the work of the association in the railroad and civic fields, of its service department and of its efforts to promote ethics. A. E. Holcomb reviewed local work along similar lines.

President Wilson has signed the oil-land leasing bill, which opens up for development millions of acres of land in the west. The total area thrown open for lease under the bill is estimated by the Geological Survey at more than 6,700,000 acres, while proven coal lands under Government withdrawal total approximately 30,000,000 acres, with 39,000,000 acres still to be classified.



IF DREAMS CAME TRUE

Obituary

Harold M. Davis, advertising manager of the Sprague Electric Works, died at his home in Brooklyn on Feb. 9, after a lingering illness. Mr. Davis was born in Jerseyville, Ill., Aug. 26, 1860, and was the son of Samuel W. and Mary J. McGill Davis. His early boyhood was spent in Paola, Kansas, and after finishing high school he secured a position as office boy in a lead and oil factory, later receiving an appointment as chief clerk of the St. Louis United States Assay Office. A government position was too slow and uncertain for him, however, so he came to New York to study architecture. The financial panic of 1893 offered a chance to get into the advertising line, in which he had had some experience while in St. Louis, and for four years he was advertising manager of a trade paper in New York, later becoming connected with an advertising agency and finally, in 1899, he was made manager of the advertising department of Sprague Electric Works of the General Electric Company.

Personals

F. M. Nourse joined the Chas. L. Benjamin organization at Chicago on January 1st. Mr. Nourse has been engineer in the advertising department of the Cutler-Hammer Manufacturing Co. at Milwaukee for the past two years and prior to that was associated with the Wisconsin Power, Light and Heat Co. at Portage, Wisconsin. He is a University of Illinois graduate in electrical engineering and worked for the Public Service Company of Northern Illinois both before and after his graduation.

W. K. Eicher, formerly with the General Electric Co. of Detroit, is now associated with the C. H. Wheeler Manufacturing Co., with headquarters at the Marquette Building, Chicago.

Engineering Affairs

The American Association of Engineers has adopted a policy of appropriating for the furtherance of license legislation a reasonable amount of money from the general fund equal to that raised by any state society, either alone or in conjunction with any other chapter or society. Under such an arrangement the proposed bill and the general plan of campaign must be submitted to the board of directors of the association for approval.

A. A. E. OFFERS NATIONAL UNITY PLAN

A plan for a unified engineering organization for the United States is contained in an announcement made by the American Association of Engineers that one-half the entrance fee of $10 will be waived to applicants who are members of recognized national and local engineering societies and clubs of the United States. This arrangement will be in effect only until the sixth annual convention to be held May 10, 11 and 12 in St. Louis, unless it is extended by the convention. The resolution is as follows:

"Inasmuch as the support in membership of every professional engineer in the United States is needed by the American Association of Engineers to accomplish professional unity, and inasmuch as many engineers have helped the profession by giving time and money for a number of years to that end through recognized societies and clubs:

"Be it resolved, that until the 1920 convention (May 10-11) the membership committee be authorized to waive one-half of the entrance fee of $10 to applicants who are in good standing in such recognized clubs and societies and to accept such applications when accompanied by an entrance fee of $5."

Business Items

E. R. Ladew, Inc., the large leather belting concern at Glen Cove, L. I., has been sold to Graton & Knight, leather belting manufacturers at Worcester, Mass. Millions of dollars are involved in the deal.

THE COAL MARKET

BOSTON—Current prices per gross ton f.o.b. New York loading ports:

Anthracite

	Company Coal
Egg	$8.20@$8.65
Stove	8.45@ 9.05
Chestnut	8.55@ 9.05
Pea	7.05@ 7.40
Buckwheat	3.60@ 3.80
Rice	2.30@ 2.50
Barley	1.25

Bituminous

	Clearfields	Cambrias and Somersets
F.o.b. mines, net tons	$2.85@$3.35	$3.15@$3.60
F.o.b. Philadelphia, gross tons	5.05@ 5.60	5.35@ 5.90
F.o.b. New York, gross tons	5.40@ 5.95	5.75@ 6.25
Alongside Boston (water coal), gross tons	7.00@ 7.75	7.60@ 8.00

Pocahontas and New River are practically off the market for coastwise shipment, but are quoted at $6.25@$7.00.

NEW YORK—Current quotations, White Ash, per gross tons, f.o.b. Tidewater, at the lower ports are as follows:

Anthracite

	Company Coal
Broken	$7.80@$8.25
Egg	8.20@ 8.65
Stove	8.45@ 9.05
Chestnut	8.55@ 9.05
Pea	7.05@ 7.40
Buckwheat	5.15
Rice	4.50
Barley	4.85
Boiler	4.85

Bituminous

Government prices at mines:	Spot
South Fork (best)	$3.25@$3.50
Cambria (best)	3.00@ 3.25
Cambria (ordinary)	2.60@ 2.90
Clearfield (best)	3.00@ 3.25
Clearfield (ordinary)	2.60@ 2.90
Reynoldsville	2.85@ 2.90
Quemahoning	3.25@ 3.50
Somerset (medium)	3.00@ 3.25
Somerset (poor)	2.50@ 2.75
Western Maryland	2.50@ 2.75
Fairmont	2.25@ 2.50
Latrobe	2.60@ 2.90
Greensburg	2.75@ 3.00
Westmoreland ¾ in.	3.40@ 3.50
Westmoreland run-of-mine	2.75@ 3.00

PHILADELPHIA—Bituminous coal prices vary according to district from which they are mined. For ordinary slack the price is $2.45@$2.55; lump, $3.00@$3.35, at the mines.

BUFFALO—

Anthracite

	On Cars, Gross Ton	At Curb, Net Ton
Grate	$8.55	$10.80
Egg	8.80	10.65
Stove	9.00	10.85
Chestnut	9.10	10.85
Pea	7.75	9.30
Buckwheat	5.70	7.75

Bituminous

Allegheny Valley	$4.80
Pittsburgh	4.65
No. 8 Lump	4.65
Mine Run	4.80
Slack	4.10
Smokeless	4.60
Pennsylvania Smithing	5.70

CLEVELAND—Prices of coal per net ton delivered in Cleveland are:

Anthracite

Egg	$12.25@$12.40
Chestnut	12.50@ 12.70
Grate	12.25@ 12.40
Stove	12.40@ 12.60

Pocahontas

Mine-run	$7.50

Domestic Bituminous

West Virginia split	$8.50
No. 8 Pittsburgh	$6.60@ 6.90
Massillon lump	8.25@ 8.50
Coshocton lump	7.15

Steam Coal

No. 6 slack	$5.25@$5.50
No. 8 slack	5.10@ 5.50
Youghiogheny slack	5.25@ 5.50
No. 8 ¾ in.	5.70@ 6.00
No. 6 mine-run	5.25@ 5.50
No. 8 mine-run	5.75

Only coal available is mine-run Pocahontas.

MIDDLE WEST—Chicago quotations, F.o.b. cars at mine:

	Springfield, Carterville, Williamson, Franklin, Saline, Harrisburg	Fulton, Peoria	Grundy, La Salle, Bureau, Will
Lump	$2.55@$2.70	$2.95@$3.10	$3.25@$3.40
Washed	2.75@ 2.90	.....	3.45@ 3.60
Mine run	2.35@ 2.50	2.75@ 2.90	3.00@ 3.15
Screenings	2.05@ 2.20	2.35@ 2.50	2.75@ 2.90

New Construction

PROPOSED WORK

Mass., Boston—The Olympia Theatres, Inc., 35 Piedmont St., plan to construct an 11 story, 88 x 300 ft. theatre and office building on Washington and Milk Sts. A steam heating system will be installed in same. Total estimated cost, $1,000,000. G. U. Crocker, Pres.

Mass., East Springfield—The Westinghouse Electric Co., 6905 Susquehanna St., will soon award the contract for the construction of a 1 story machine shop at its plant. A steam heating system will be installed in same. Total estimated cost, $360,000.

Mass., Lowell—O'Connell & shaw, Archts., 18 Boylston St., Boston, will soon award the contract for the construction of a 7 story, 80 x 100 ft. hotel on Middle St., for F. E. Harris, c/o Hotel Harrisonia. A steam heating system will be installed in same. Total estimated cost, $175,000.

Mass., Newton Upper Falls—Lockwood, Green & Co., Engrs., 60 Federal St., Boston, will receive bids about March 1 for the construction of a 2 story, 200 x 350 ft. foundry, for the Saco-Lowell Shops, 77 Franklin St., Boston. Electric motors for power will be installed in same. H. M. Lane Co., 701 Owen Bldg., Detroit, Mich., Engr.

Mass., Northampton—Charles F. Atkinson, c/o Funk & Wilcox, Archts., 1148 Old South Bldg., Boston, plans to construct a 1 and 2 story, 85 x 190 ft. theatre and business building on King St. A steam heating system will be installed in same. Total estimated cost, $150,000.

N. Y., Albany—Charles F. Rattigan, Supt. of Prisons, Capitol, Albany, will receive bids until March 9 for the construction of underground tunnels and installation of underground heating mains, sewer and water connections, etc. Separate bids will be received for the construction, heating, sanitary and electric work.

N. Y., Hornell—The Wayne Power Co., Sodus, plans to construct a 30 mi. high tension transmission line from here to Wallace. Estimated cost, between $35,000 and $40,000.

N. Y., New York (Borough of Bronx)—The Bd. of Educ., 500 Park Ave., Manhattan, will receive bids about March 4 for the construction of a 5 story school at Crotona Park and Charlotte Ave. A steam heating system will be installed in same. Total estimated cost, $500,000. C. B. J. Snyder, Municipal Bldg., Manhattan, Archt. and Engr.

N. Y., New York (Borough of Bronx)—The Bd. of Educ., 500 Park Ave., Manhattan, will receive bids about March 4 for the construction of a 5 story, 230 x 280 ft. school on Southern Blvd. and Leggett Ave. A steam heating system will be installed in same. Total estimated cost, $600,000. C. B. J. Snyder, Municipal Bldg., Manhattan, Archt. and Engr.

N. Y., Brooklyn—Dodge & Morrison, Archts. and Engrs., 135 Front St., New York City, will soon award the contract for the construction of a 4 story, 50 x 100 ft. factory at 28 Waverly Ave., for the Empire Biscuit Co., 30 Waverly Ave. A steam heating system will be installed in same. Total estimated cost, $100,000.

N. Y., Long Island City—The Title Guarantee & Trust Co., 176 B'way, New York City, is having plans prepared for the construction of an office building on Hunter Ave. and the Queenboro Bridge Plaza. A steam heating system will be installed in same. Total estimated cost, $100,000. Severence & Van Allen, 111 East 40th St., New York City, Archts. and Engrs.

N. Y., Marcy—The State Hospital Comn., Capitol, Albany, N. Y., will receive bids until March 3 for the installation of a heating system in the tuberculosis pavilion and mortuary, at the Utica State Hosptal, here.

N. Y., New York—R. A. Gershee, c/o F. P. Kelly, Archt. and Engr., 477 5th Ave., is having plans prepared for the construction of a 25 story, 25 x 100 ft. office, show room and cafeteria at 138 West 43rd St. A steam heating system will be installed in same. Total estimated cost, $2,000,000.

N. Y., New York—The Canadian Bank of Commerce, 16 Exch. Pl., is having plans prepared for altering the present 8 story bank and office building, and building a 2 story addition. A steam heating system will be installed in same. Total estimated cost, $500,000. A. F. Gilbert, 80 Maiden Lane, Archt. and Engr.

N. Y., New York—R. Dunther and R. Law, Inc., 25 Broad St., are having plans prepared for the construction of a 7 story, 40 x 50 ft. office building at 131 Cedar St. A steam heating system will be installed in same. Total estimated cost, $160,000. A. F. Gilbert, 80 Maiden Lane, Archt. and Engr.

N. Y., New York—H. A. Jacobs, Archt. and Engr., 320 5th Ave., will soon award the contract for the construction of a 6 story, 25 x 100 ft. store and office building at 675 5th Ave., for H. D. Downs, 552 3rd Ave. A steam heating system will be installed in same. Total estimated cost, $85,000.

N. Y., New York—B. H. and C. N. Whinston, Archts. and Engrs., 2 Columbus Circle, will soon award the contract for the construction of three 5 story loft buildings at 117-119-121 West 33rd St., for the 121st West 33rd St. Corp. A steam heating system will be installed in same. Total tstimated cost, $150,000.

N. Y., New York—The Munson Steamship Line, 82 Beaver St., is having plans prepared for the construction of a 25 story, 22 x 144 x 160 ft. office building on Pearl St., between Beaver and Wall Sts. A steam heating system will be installed in same. Total estimated cost, $2,000,000. K. M. Murchison, 101 Park Ave., Archt. and Engr.

N. Y., New York—The New York Telephone Co., 15 Dey St., is having plans prepared for the construction of a 5 story telephone exchange on 30th St. and 2nd Ave. A steam heating system will be installed in same. Total estimated cost, $1,000,000. McKenzie, Voorhies & Gmelin, 1123 B'way, Archts. and Engrs.

N. Y., New York—F. E. Vibolo, Archt. and Engr., 56 West 45th St., is preparing plans for the construction of a 10 story office building on Franklin St. and West B'way. A steam heating system will be installed in same. Total estimated cost, $200,000. Owner's name withheld.

N. Y., Oneida—The Adirondack Electric Power Corp., 16½ Lenox Ave., plans to extend its transmission line from here to Munnsville and Stockbridge. Estimated cost, between $12,000 and $15,000.

N. Y., Peekskill—St. Mary's Community is having plans prepared for the construction of a school and gymnasium. A steam heating system will be installed in same. Total estimated cost, $325,000. C. P. H. Gilbert, 1123 B'way, New York City, Archt. and Engr.

N. Y., Watertown—H. H. Babcock, Factory Sq., plans to increase the hydro-electric power by modern development of present rights. Plans include construction of power house and installation of generator, etc. Total estimated cost, $100,000.

N. Y., Woodhaven—The Merritt Hosiery Co., c/o Bloch & Hesse, Archts., 18 East 41st St., will soon award the contract for the construction of a 4 story, 60 x 180 ft. factory on 104th St. A steam heating system will be installed in same.

N. J., Glassboro—The state plans to build a 2 story, 42 x 79 ft. power house, to be used for the proposed normal school, including a 26 x 79 ft. coal bunker, 16 x 32 ft. water tank, fire pump, heater, three 360 hp. boilers and 2 generators. Total estimated cost, $100,000. F. H. Bent, 142 West State St., Trenton, Archt.

N. J., Jersey City—The Continental Can Co. is having plans prepared for the construction of a 4 story factory at 15th, 16th, Cole and Monmouth Sts. A steam heating system will be installed in same. Total estimated cost, $750,000. Francisco & Jacobus, 511 5th Ave., New York City, Archts. and Engrs.

N. J., Rahway—The state plans to build a 2 story, 45 x 120 ft. refrigerator plant, etc., at the Rahway Reformatory. Estimated cost, $20,000. F. H. Bent, 142 West State St., Trenton, Archt.

N. J., South River—The Borough Pres. will receive bids about March 1 for the construction of a 1 story, 55 x 100 ft. power house, for the Bd. Pub. Wks. Estimated cost, $125,000. Goss, Bryce & Johnson, 55 Liberty St., New York City, Archts. and Engrs.

Pa., Bethlehem—The Bethlehem Natl. Bank plans to build a 5 story, 40 x 150 ft. bank. A steam heating system will be installed in same. Total estimated cost, $150,000.

Pa., Philadelphia—The Arcadia Cafe, Widener Bldg., will have plans prepared for the construction of a 1 story chateau at Fairmount Park. A steam heating system will be installed in same. Total estimated cost, $300,000. Ralph E. White, Penna Bldg., Archt. and Engr.

Pa., Philadelphia—The Apperson Motor Car Co., Broad and Race Sts., is having plans prepared for the construction of a 6 story, 75 x 100 ft. service building on Girard and Broad Sts. A steam heating system will be installed in same. E. H. Yardley, 1713 Sansom St., Archt.

Pa., Philadelphia—Heacock & Hohansen, Archts. and Engrs., Bailey Bldg., will soon award the contract for the construction of a 4 story, 40 x 90 ft. warehouse at 810 Queen St., for the Hagy Waste Wks., 836 South Swanson St. A steam heating system will be installed in same.

Pa., Philadelphia—The Keller Eng. Serv. Co., Otis Bldg., is having plans prepared for the construction of a 4 story, 70 x 125 ft. store and office building on 16th and Sansom Sts. A steam heating system will be installed in same. Total estimated cost, $150,000. Simon & Simon, 249 South Juniper St., Archts.

Pa., Phillipsburg—George S. Idell, Archt., 1705 Chestnut St., Philadelphia, will soon award the contract for the construction of a 6 story, 80 x 100 ft. hotel building, here, for the Phillipsburg Hotel Corp. A steam heating system will be installed in same. Total estimated cost, $100,000.

Pa., Pittsburgh—William Allen Balch, Archt., 756 Woodward Ave., Detroit, is preparing plans for the construction of a 5 story, 57 x 224 garage and service station. Steam heating equipment will be installed in same. Total estimated cost, $200,000. Owner's name withheld.

Pa., Reading—S. S. Kresge Co., Kresge Bldg., Detroit, engaged J. E. Mills & Son, Archts., 1305 Kresge Bldg., Detroit, to prepare plans for altering and constructing a 4 story, 50 x 270 ft. addition to mercantile building. Steam heating equipment will be installed in same. Total estimated cost, $100,000.

Pa., Scranton—Edward H. Davis and George M. D. Lewis, Associate Archts., Union Natl. Bank, are preparing plans for the construction of a 3 story, 50 x 145 ft. warehouse on Locka Ave. A steam heating system will be installed in same. Total estimated cost, $110,000. Owner's name withheld.

Pa., Scranton—Edward H. Davis and George M. D. Lewis, Archts., Union Natl. Bank Bldg., are preparing plans for the construction of a 3 story, 55 x 150 ft. factory on Washington Ave. A steam heating system will be installed in same. Total estimated cost, $175,000. Owner's name withheld.

Pa., Windber—The Windber Hospital is having plans prepared for the construction of 2 story, 35 x 90 ft. and 30 x 50 ft. hospital buildings. A steam heating system will be installed in same. Henry L. Reinhold Jr., 1513 Walnut St., Philadelphia, Archt.

O., Cincinnati—The Second Church of Christ Scientist will soon receive bids for the construction of a 2 story, 90 x 120 ft. church on Clifton and Probasco Aves. An indirect heating and ventilating system will be installed in same. Total estimated cost, $175,000. Arthur Neal Robinson, Candler Bldg., Atlanta, Ga., Archt.

O., Cleveland—The Babies Dispensary & Hospital, 2500 East 35th St., is having plans prepared for the construction of a 7 story, 60 x 120 ft. hospital on Adelbert and Euclid Aves. A steam heating system will be installed in same. Total estimated cost, $600,000. E. B. Green, Treas. Abram Garfield, 915 Natl. City Bldg., Archt.

O., Cleveland—Christian, Schwarzenburg & Gaede Co., Archts. and Engrs., 1900 Euclid Ave., will soon award the contract for the construction of a 3 story, 96 x 221 ft. textile factory on Buckeye Rd. near East 104th St., for Schaffner Bros., 1013 Oregon Ave. Two boilers will be installed in same. Total estimated cost, $150,000.

O., Cleveland—The city will soon award the contract for installing two 850 gal. per min. centrifugal boiler feed pumps. Estimated cost, $10,000. Edward Shattuck, Purch. Agt. R. Hoffman, City Hall, Engr.

O, Cleveland—The Creswell Realty Co., Union Bldg., is having plans revised for the construction of an 8 story, 100 x 125 ft. garage on Huron Rd. and East 12th St. A steam heating system will be installed in same. Total estimated cost, $500,000. W. S. Ferguson Co., 1900 Euclid Ave., Archts. and Engrs.

O., Cleveland—The Detroit Lake Ave. Co., Sloan Bldg., will receive bids after March 1 for the construction of a 6 story, 190 x 232 ft. theatre and office building on Detroit and Lake Aves. A steam heating system will be installed in same. Total estimated cost, $600,000. G. W. Armstrong, Pres.

O., Cleveland—Emmett P. and John L. Dowling, Williamson Bldg., plan to build a 6 story commercial building on East 14th St. and Caton Court. A steam heating system will be installed in same. Total estimated cost, $250,000.

O., Cleveland—The Labor Lyceum Co., 2460 East 9th St., plans to build an 8 story Labor Temple on East 18th St. near Prospect Ave. A steam heating system will be installed in same. Total estimated cost, $300,000. Charles Smith, Secy. W. S. Longee, Marshall Bldg., Archt.

O., Cleveland—Charles Neuburger, Statler Hotel, Euclid Ave. and East 12th St., plans to build a 2 or 8 story, 75 x 200 ft. commercial building on Euclid Ave., near East 32nd St. A steam heating system will be installed in same. Total estimated cost, $200,000.

O., Cleveland—The Realty & Investment Co., c/o G. A. Tenbusch, Union Bldg., will soon award the contract for the construction of a 6 story, 100 x 200 ft. commercial building on East 65th St. and Euclid Ave. A steam heating system will be installed in same. Total estimated cost, $400,000. W. S. Ferguson Co., 1900 Euclid Ave., Archt. and Engr.

O., Cleveland—Frank N. Riley, 309 Williamson Bldg., is having plans prepared for the construction of a 4 story, 116 x 240 ft. commercial building on East 79th St. and Hough Ave. A steam heating system will be installed in same. Total estimated cost, $250,000. J. Milton Dyer, Amer. Trust Bldg., Archt.

O., Cleveland—St. Luke's Hospital, 6606 Carnegie Ave., is having preliminary plans prepared for the construction of a 6 story hospital on Fairmount Blvd. Three boilers with necessary equipment will be installed in same. Total estimated cost, $750,000. Hubbell & Benes, 4500 Euclid Ave., Archts.

O., Columbus—The Bd. Comrs. Franklin Co., Court House, will receive bids until March 4 for the construction of a 2 story tuberculosis hospital on the Infirmary grounds. A steam heating system will be installed in same. Total estimated cost, $125,000. W. H. Tremaine, 602 Chamber of Commerce Bldg., Archt.

O., Lakewood (Cleveland P. O.)—The Bd. Educ. plans to build a 2 story school to be known as the Lincoln School. A steam heating system will be installed in same. Total estimated cost, $300,000. G. W. Grill, Warren Rd., Clk. C. W. Hopkinson, 900 Rose Bldg., Cleveland, Archt.

O., Massillon—William Tilberth, Clk. Bd. Educ., will soon award the contract for the construction of a 2 story, 70 x 95 ft. school. A steam heating system will be installed in same. Total estimated cost, $125,000. O. D. Howard, 8 East Broad St., Columbus, Archt.

O., Norwood—The city plans to restore the municipal electric light plant which was destroyed by fire. Sidney Crew, City Hall, Engr.

O., Parma—The Bd. Educ. plans to build three 1 story, 60 x 120 ft. school buildings. Steam heating systems will be installed in same. Total estimated cost, $400,000. Charles W. Bates, Natl. Bank Bldg., Wheeling, W. Va., Archt.

O., Springfield—S. S. Kresge Co., High St., is having plans prepared for the construction of a 4 story, 50 x 130 ft. business building on Main St. A steam heating system will be installed in same. Total estimated cost, $150,000. Hall & Lethly, 807 Fairbanks Bldg., Archts.

O., Troy—The city plans to build a 1 story, 40 x 60 ft. electric light plant on East Water St. Estimated cost, $20,000. Address V. S. Deaton, Mayor.

Mich., Bay City—A. E. Munger, Archt., 420 Shearer Office Bldg., will soon award the contract for the construction of a 3 story, 250 x 350 ft. automobile body factory addition, for the Wilson Body Co. A steam heating system will be installed in same. Total estimated cost, $500,000.

Mich., Detroit—The Bd. Educ., 50 B'way, engaged Malcolmson, Higginbotham & Palmer, Archts., 405 Moffat Bldg., to prepare plans for the construction of a 2 story, 90 x 150 ft. school on the north side of Charles Ave. A Plenum steam heating system and ventilating system will be installed in same. Total estimated cost, $200,000.

Mich., Detroit—The Detroit Baptist Union, 1105 Vinton Bldg., plans to build a 2 story, 64 x 120 ft. church on Jefferson Ave. and Lakewood Blvd. A steam heating system will be installed in same. Total estimated cost, $125,000. Dalton R. Wells, 435 Woodward Ave., Archt. and Engr.

Mich., Detroit—The Standard Accident Insurance Co., 34 Fort St., W., engaged Albert Kahn, Archt., Marquette Bldg., to prepare plans for the construction of an 8 story office building on Bagg St. and Cass Park. A steam heating system will be installed in same. Total estimated cost, $500,000.

Mich., Flint—St. Michael's Parish, 6th St., is having plans prepared for the construction of a 2 story, 62 x 245 ft. school on 6th St. A steam heating system will be installed in same. Total estimated cost, $250,000. Van Leyen, Schilling & Keough, 1115 Union Trust Bldg., Detroit, Archts. and Engrs.

Mich., Northville—C. Frieburger, Secy. Bd. of Health, 233 St. Antoine St., Detroit, will receive bids until March 1 for the construction of a 1 story, 40 x 120 ft. power plant, in connection with the group of buildings to be constructed at the proposed Detroit Municipal Tuberculosis Sanitarium. A steam heating system, including feed water heater, pump, etc., will be installed in same. Stratton & Snyder, 1103 Union Trust Bldg., Detroit, Archts.

Mich., Northville—L. A. Young, 93 Rhode Island Ave., Detroit, is having plans prepared for the construction of a country estate, including a 150 x 350 ft. barn and a 2 story, 30 x 50 ft. garage. A steam heating system will be installed in same. Total estimated cost, $200,000. C. W. Brandt, Kresge Bldg., Detroit, Archt.

Ill., Chicago—H. C. Miller, Archt., 112 West Adams St., will soon award the contract for the construction of a 3 story, 120 x 140 ft. paper box factory at 1701 West Superior St., for the Kroeck Paper Box Co., 220 Institute Pl. A steam heating system will be installed in same. Total estimated cost, $175,000.

Wis., Manitowoc—The city plans to raise funds for the construction of a 3 story, 60 x 180 ft. armory. A steam heating system will be installed in same. Total estimated cost, $125,000. A. Zarder, Clk.

Wis., Milwaukee—Geuder, Paeschke & Frey, St. Paul Ave. and 15th St., are having plans prepared for the construction of a 1 story, 75 x 100 ft. power plant on St. Paul Ave. Three 300 hp. W.T. boilers, superheater, switchboard and handling equipment will be installed in same. Total estimated cost, $150,000. Cahill & Douglas, 217 West Water St., Engrs.

Wis., Saukville—H. J. Cary, Pres. of the Ozaukee Heating Co., has purchased a site and plans to build a 2 story, 36 x 376 ft. pea canning factory on Main St., and is in the market for several boilers, etc. Total estimated cost, $40,000.

Wis., Sheboygan—The Security Natl. Bank, 529 North 8th St., will soon receive bids for the construction of a 4 story, 60 x 110 ft. bank and office building on Center and 8th Sts. A steam heating system will be installed in same. Total estimated cost, $250,000.

Wis., Waupaca—J. G. D. Mack, State Chief Engr., Capitol Bldg., Madison, will receive bids until March 2 for the entire reconstruction of the power house at the Wisconsin Veterans' Home, here.

Iowa, Fairfield—The Bd. Educ. will soon receive bids for the construction of a 2 story, 68 x 118 ft. junior high school. A steam heating system will be installed in same. Total estimated cost, $150,000. W. Gordon, 317 Hubbell Bldg., Des Moines, Archt.

Iowa, Grinnell—The Bd. Educ. plans to build a 2 story high school. A steam heating system will be installed in same. Total estimated cost, $300,000. W. Ray, Secy.

Minn., Arlington—The village Clerk will soon award the contract for the installation of one power pump head, double or single stroke, 24 in. stroke, to pump water from well 317 ft. deep, 2 in. cylinder, being 160 ft. in well, into elevated tank 110 ft. from ground. Driven by 18 in. pulley running 327 r.p.m., pulley 1 pump head to conform to give 30 strokes per min.

Minn., Duluth—The Duluth Builders' Exch., 201 Glencoe Bldg., 1st St., plans to construct a 10 story, 100 x 140 ft. office building on 1st St., W. A steam heating system will be installed in same. Total estimated cost, $750,000.

Minn., Minneapolis—The Bureau of Engraving, 17 South 6th St., is having plans prepared for the construction of a 4 story, 100 x 130 ft. business building on Mary Pl. at 12th St. A steam heating system will be installed in same. Total estimated cost, $200,000.

Kan., Abilene—The city plans to extend the water mains and build a 100,000 gal. tank on an 80 ft. tower. Total estimated cost, $40,000.

Neb., Omaha—The Ames Realty Co., 2406 Ames Ave., will soon award the contract for the construction of a 3 story, 125 x 133 ft. theatre, store and apartment building on 25th St. and Ames Ave. A steam heating system will be installed in same. Total estimated cost, $200,000. Everett S. Dodds, 715 Brandeis Theatre Bldg., Archt.

Mo., Carthage—Shepard & Wiser, Archts., R. A. Long Bldg., Kansas City, will soon award the contract for the construction of a 5 story, 75 x 90 ft. building on 4th and Howard Sts., for the Chamber of Commerce. A hot water heating system and electric elevator will be installed in same. Total estimated cost, $140,000.

Mo., Kansas City—Keene & Simpson, Archts., 400 Reliance Bldg., are receiving bids for installing a steam heating system in the proposed 10 story, 110 x 115 ft. office building on 19th and Walnut Sts., for T. C. Bourke, 3520 B'way.

Okla., Pryor Creek—The city plans to hold an election to vote on $75,000 bonds for the construction of a filter plant, and 8 mi. of 200 kw. 6,600 volt transmission line transformers at both ends of line, also the installation of two 2,200 volt, 75 kw. high pressure motor driven centrifugal pumps and two 15 kw. and one 20 kw. low pressure motor driven centrifugal pumps. Total estimated cost, $75,000. V. V. Long & Co., 1200 Colcord Bldg., Oklahoma City, Engr.

Colo., Boulder—Walter S. and L. D. Cambell head company which has been formed to build a pipe line and power house, here. Total estimated cost, $150,000.

Wash., Spokane—The Bd. of Trustees of Whitworth Presbyterian College, Spokane Estates, plan to build a 1 and 2 story building to cost $100,000, women's dormitory, $75,000, and a central heating plant, $75,000, on the college campus. A. Beatie, Pres.

Ore., Canby—The city plans to reconstruct the pump house and install new pumping machinery for the waterworks system. Estimated cost, $7,500. A special election will be held April 19 to vote on bonds for this project.

Ore., Klamath Falls—The Ewauna Box Co. plans to install 1 gang outfit, with a 100,000 ft. capacity every 8 hours, one 9 ft. band saw, also 1 steam boiler. Cost to exceed $10,000. F. H. Hunter, Archt.

Ore., Lebanon—The Lebanon Electric Light & Water Co. plans to double the size of its power plant by constructing a new plant on the west side of Main St. and north side of Canal St., including 3 mi. flume, 2 water wheels, concrete dam, etc., also the installation of new pumping equipment and electric motors. Total estimated cost, $75,000.

Ore., Portland—The Comrs. Multnomah Co., Court House, plan to install one 40 hp. gas or oil burning engine at Hoyt Quarry. Estimated cost, $1,000. R. W. Hoyt, Chmn.

Cal., Bakersfield—The San Joaquin Light & Power Co., 122 Tulare St., plans to build a power plant 35 mi. west of here, where natural gas now going to waste will be used to generate electric power. First unit will cost $1,000,000; ultimate cost, $6,000,000.

Cal., San Diego—The Pub. Wks. Office, 12th Naval Dist., Timken Bldg., San Diego, will receive bids until March 3 for furnishing and installing complete power plant and electric generating equipment, including piping, distribution systems for electric and steam power, 2 oil burning boilers, oil pumps, feed water heater, 2 engine driven alternators, 1 engine driven and 1 electric driven excitor, transformers, vacuum pump, separating tank, etc., for the Marine Corps Base, here. Total estimated cost, $150,000.

Cal., Lancaster—The Bd. Supervs. of Los Angeles Co. will soon award the contract for the installation of a distributing system, well and pit, 75,000 gal. steel tank on a 90 ft. steel tower, vertical plunger pump with motor to lift 170 gal. per min., and construction of pump house, in Los Angeles Co. Waterworks Dist 4. Estimated cost, $30,000. W. Davidson, Hall of Records, Los Angeles, Engr.

Cal., Long Beach—The city voted $500,000 bonds to improve the water system, including reservoir, pumping equipment and mains. H. C. Waughop, City Clk. A. DeRuez, City Engr.

Cal., Orange—The City Trustees plan to hold an election to vote on bonds to install a well and pump. D. G. Wettlin, City Clk. W. J. Richardson, Water Supt.

Cal., Tujunga—The Haines Canyon Water Co. is having plans prepared for the construction of 2 earth reservoirs with 10 in. connecting pipe line and motor driven pumps. Total estimated cost, $17,000. H. B. Lynch, 314 South Brand Bldg., Glendale, Engr.

Ont., London—L. V. Carrothers, Archt., Hydro Offices, will receive bids until April 1 for the construction of two 3 story, 100 x 185 ft. schools in the southern part of the city, for the Bd. Educ., City Hall. A steam heating system will be installed in same. Total estimated cost, $275,000.

CONTRACTS AWARDED

Me., Deer Rips (Lewiston P. O.)—The Androscoggin Light & Power Co. has awarded the contract for the construction of a power house addition, here, to the Landeis Engr. Co., 102 Exch. St., Portland. Boilers, electrical equipment and heating and power machinery will be installed in same. Total estimated cost, $50,000.

Mass., Boston—The Federal Reserve Bank, 58 State St., has awarded the contract for the construction of a 5 story bank on Pearl and Milk Sts., to L. P. Soule & Co., 80 Boylston St. A steam heating system will be installed in same. Total estimated cost, $4,500,000.

Mass., Boston—S. S. Kresge Co., Kresge Bldg., Detroit, Mich., has awarded the contract for the construction of a 6 story, 90 x 90 ft. store building on Washington and Temple Sts., to George A. Fuller Co., 710 Bd. of Trade Bldg. A steam heating system will be installed in same. Total estimated cost, $400,000.

Mass., Lowell—The city has awarded the contract for the construction of a 2 story, 150 x 150 ft. memorial hall on River St., to George Drapeau. A steam heating system will be installed in same. Total estimated cost, $750,000.

Mass., Robert's Crossing (Boston P. O.)—W. C. Welch Co. has awarded the contract for the construction of a 2 story, 40 x 100 ft. factory, including boiling house, fire room and garage, to R. F. Morrison Co., Charlestown (Boston P. O.).

R. I., Providence—L. E. Danforth, 76 Dorrance St., will build a 3 story, 90 x 100 ft. factory and office building on Willard Ave. A steam heating system will be installed in same. Total estimated cost, $125,000. Work will be done by day labor.

Conn., Derby—The Derby & Ansonia Brewing Co., Derby Ave., has awarded the contract for the construction of a 2 story, 33 x 100 ft. ice plant on Derby Ave., to M. A. Durrschmidt, Main St. Estimated cost, $25,000.

Conn., Derby—The Derby Gas Co., 22 Elizabeth St., has awarded the contract for the construction of a 2 story, 42 x 100 ft. boiler house on Housatonie Ave., to M. A. Durrschmidt, Main St. Estimated cost, $35,000.

N. Y., Buffalo—The Dunlap Rubber Co., 1808 B'way, New York City, has awarded the contract for the construction of a factory consisting of twelve 1 and 2 story buildings, to the Foundation Co., 233 B'way, New York City. A steam heating system will be installed in same. Total estimated cost, $20,000,000.

N. Y., Long Island City—The Metropolitan Life Insurance Co., 1 Madison Ave., New York City, has awarded the contract for the construction of a 5 story, 50 x 400 ft. printing building on Court St. and Thompson Ave., to the Turner Constr. Co., 244 Madison Ave., New York City. A steam heating system will be installed in same. Total estimated cost, $1,000,000.

N. Y., New York (Borough of Bronx)—The Jackson Film Corp., 143 B'way, Manhattan, will build a 180 x 224 ft. film studio on Webster and Jackson Aves. A steam heating system will be installed in same. Work will be done by day labor.

N. Y., Brooklyn—The Kraslow Bldg. Co., Inc., 190 Montague St., will build a 12 story office building at 180-186 Montague St. A steam heating system will be installed in same. Total estimated cost, $1,000,000. Work will be done by day labor.

N. Y., Brooklyn—L. Mundet & Sons, 59 Pearl St., New York City, will build a 4 story, 200 x 200 ft. factory on King and Ferris Sts., Ridgewood. A steam heating system will be installed in same. Total estimated cost, $400,000. Work will be done by day labor.

N. Y., Brooklyn—J. Rubin & Son, 142 Greene Ave., will build a 3 story, 100 x 100 ft. factory on Grand and Park Aves. A steam heating system will be installed in same. Total estimated cost, $150,000.

N. Y., Brooklyn—The Union Elton Co., 1784 Pitkin Ave., will build four 4 story, 40 x 90 ft. factory buildings at 2402-2430 Atlantic Ave. A steam heating system will be installed in same. Total estimated cost, $200,000. Work will be done by day labor.

N. Y., New York—B. Altman, 5th Ave., 34th St., has awarded the contract for the construction of an 8 story, 60 x 100 ft. department store at East 35th St., to Marc Eidlitz, 30 East 42nd St. A steam heating system will be installed in same.

N. Y., New York—H. L. Schraffts Co., 157 West 54th St., has awarded the contract for the construction of a 4 story factory at 161 West 64th St., to the Bethlehem Eng. Co., 527 5th Ave. A steam heating system will be installed in same. Total estimated cost, $140,000.

N. J., Athenia—The Magor Car Co. has awarded the contract for the construction of a 1 story, 40 x 60 ft. power house, to W. Hassen, 625 Main St., Passaic. A steam heating system will be installed in same. Total estimated cost, $35,000.

N. J., Clifton—The Clifton Textile Co., 128 Hackensack Plank Rd., will build a 1, 2 and 3 story, 250 x 350 ft. factory, consisting of 6 buildings. A steam heating system will be installed in same. Total estimated cost, $600,000. Work will be done by day labor.

N. J., Jersey City—The W. M. Crane Co., Garfield Ave., has awarded the contract for the construction of two or three 1 story foundry buildings, to Ballinger & Perrot, 17th and Arch Sts., Philadelphia. A steam heating system will be installed in same. Total estimated cost between $200,000 and $300,000.

N. J., Trenton—The Agasote Millboard Co., Fernwood, has awarded the contract for the construction of a 1 story, 40 x 40 ft. boiler house and stack, 5 ft. base and 150 ft. high, to N. A. K. Bugbee, 206 East Hanover St. Total estimated cost, $15,000.

Pa., Johnstown—The Johnstown School Dist., 601 Swank Bldg., has awarded the contract for installing a steam heating

system in the proposed 2 story junior high school, to the Swank Hardware Co., Johnstown, at $30,224.

Pa., Philadelphia—Friedberger & Arson, 18th and Courtland Sts., have awarded the contract for the construction of a 3 story, 74 x 100 ft. factory addition on Courtland and Gratz Sts., to W. Steele & Sons Co., 16th and Arch Sts. A steam heating system will be installed in same. Total estimated cost, $100,000.

N. C., Winston-Salem—P. H. Hanes Knitting Co. has awarded the contract for the construction of a 6 story, 80 x 200 ft. knitting mill and dye house to the Southern Ferro Concrete Co., Trust Co. of Ga. Bldg., Atlanta. A steam heating system and electric power will be installed in same. Total estimated cost, $300,000.

O., Bellevue—The Bd. Educ. has awarded the contract for the construction of a 3 story, 80 x 90 ft. school, to Willing Bros., Bellevue. A steam heating system will be installed in same. Total estimated cost, $120,000.

O., Toledo—The Standard Oil Co. of Ohio, East Ohio Gas Bldg., Cleveland, has awarded the contract for the construction of a 1 story 63 x 204 ft. boiler house for its oil refinery, to James Stewart & Co., 30 Church St., New York City. Estimated cost, $100,000.

O., Troy—The city has awarded the contract for furnishing and installing a 1,000 kw. electric turbine generator for the electric light plant, to the Westinghouse Electric & Mfg. Co., Schenectady, N. Y. Address V. C. Deaton.

Ind., Indianapolis—The U. S. Corrugated Fiber Box Co. has awarded the contract for the construction of a 3 story, 100 x 160 ft. factory on Roosevelt and Martindale Aves., to C. J. Wacker, 628 Law Bldg. A steam heating system and power will be installed in same. Total estimated cost, $125,000.

Mich., Lansing—The Federal Drop Forge Co. has awarded the contract for the construction of a 1 story, 60 x 120 ft. drop forge plant, to the Christmen Constr. Co., South Bend, Ind. A power plant will be included in the project.

Ill., Chicago—The Agar Provision Co., 310 North Green St., has awarded the contract for the construction of a 4 story, 125 x 190 ft. factory on Fulton and Green Sts., to Wells Bros. Constr. Co., 53 West Jackson Blvd. A steam heating system will be installed in same. Total estimated cost, $400,000.

Ill., Chicago—The William Davies Co., Ltd., 4101 South Union Ave., has awarded the contract for the construction of a 6 story, 100 x 130 ft. meat canning plant on Union Ave. and 41st St., to Wells Bros. Constr. Co., 53 West Jackson Blvd. A steam heating system will be installed in same. Total estimated cost, $300,000.

Ill., Chicago—Charles Lange & Bros. Co., 2740 Armitage Ave., has awarded the contract for the construction of a 4 story, 75 x 125 ft. auto sales and service building on Milwaukee and Kedzie Aves., to G. Kehl & Son Co., 1225 North Maplewood St. A steam heating system will be installed in same. Total estimated cost, $135,000.

Ill., Chicago—A. Plamondon Mfg. Co., 24 North Clinton St., has awarded the contract for the construction of a 1 story, 100 x 500 ft. machine shop, foundry and factory on 52nd St. and Western Ave., to the Overland Constr. Co., 29 South La Salle St. A steam heating system will be installed in same. Total estimated cost, $250,000.

Ill., Chicago—The Tuthill Spring Co., 760 West Polk St., has awarded the general contract for the construction of a 1 and 2 story, 210 x 420 ft. auto spring factory on 31st St. and Kilbourne Ave., to C. B. Johnson & Son, 111 West Washington St. A steam heating system will be installed in same. Total estimated cost, $225,000.

Iowa, Whiting—The Bd. of Educ. of the Consolidated Dist. has awarded the contract for installing a heating system in the proposed 2 story, 60 x 150 ft. school, to Thomas Reinhardt, Le Mars, Iowa, at $34,000.

Minn., Duluth—The United Holding Co. has awarded the contract for the construction of a 2 story, 74 x 140 ft. medical building and clinic for surgery on 1st St. and 10th Ave., to the Bowman Bldg. Co., 303 Exch. Bldg. A steam heating system will be installed in same. Total estimated cost, $125,000.

Neb., Omaha—Trimble Bros., 11th and Howard Sts., has awarded the contract for the construction of a 3 story, 126 x 136 ft. warehouse and office building on 8th and Jackson Sts., to Grant Parsons, 616 Keeline Bldg. A steam heating system will be installed in same. Total estimated cost, $200,000.

Mo., Kansas City—The Mutual Drug Co., 1200 West 9th St., Cleveland, O., has awarded the contract for installing steam heating and plumbing systems in the proposed 4 story, 50 x 115 ft. business building on 20th and Main Sts., to the Magill Plumbing & Heating Co., 1320 McGee St.

Ariz., Yuma—The city has awarded the contract for the construction of 13 mi. of pipe line in Dist. 3, including a sewage pumping unit and concrete pump house, to G. S. Benson & Sons, Stimson Bldg., Los Angeles, Cal., at $91,324.

Wash., Kennewick—The Columbia Yakima Storage Co. has awarded the contract for the construction of a 2 story, 100 x 250 ft. cold storage building, to Julian S. Geneva Co., Jefferson, Iowa. A steam heating system and a 10 ton ice plant and refrigeration machinery will be installed in same. Total estimated cost, $80,000.

Ore., Portland—Wells Bros. Contg. Co., 53 West Jackson Blvd., Chicago, contractors for the proposed new building for Montgomery Ward & Co., 581 Upshur St., has awarded the contract for furnishing and installing plumbing, heating and mechanical equipment in same, to the Dausch-Weber Heating & Eng. Co., Oregon Bldg., at $150,000.

NEW INSTALLATIONS IN POWER

Pa., Wilkes-Barre—The School Bd. is in the market for 6 low pressure boilers for the heating plant. Robert Ireland, Supt. and Archt.

Md., Baltimore—The Machinery Clearing House, Wolf Bldg., 110 East Lexington St., is in the market for ¼ hp., single phase, 110 volt, 60 cycle motors. Address A. Kenny, Mgr.

Ga., Cogdell—J. M. Morse is in the market for shingle mill and lath mill machinery and for a 75 to 100 hp. boiler.

Ill., Downs Grove—The Municipal Electric Light & Waterworks plans to rebuild its transmission line. F. W. Allen, Supt.

Iowa, Britt—The Britt Light & Power Co. plans to install a 150 hp. engine and a 100 kw. generator. L. M. Goodman, Pres. and Mgr.

Iowa, Columbus—The Louisa Co. Power Co., Columbus Junction, plans to build about 40 mi. transmission line. R. L. Van Meter, Pres. and Mgr.

Iowa, Earlham—The Municipal Electric Light & Water Plant plans to extend its rural transmission lines. M. A. Thorp, Supt.

Iowa, Farragut—The Farragut Pub. Serv. Co. plans to build 2 transmission farm lines from their station. J. J. Whisler, Mgr.

Iowa, Hawarden—The Electric Light, Power & Water Dept. plans to install a 200 kva. engine generator, set boilers and build rural transmission lines. Otto Pyles, Supt.

Iowa, Jewel—The Henderson Light & Power Co. plans to build 2 transmission farm lines with 50 consumers. R. D. Henderson, Treas.

Iowa, Lorimor—The Lorimor Light & Power Co. plans to build 8 mi. 2,300 volt transmission farm lines. J. F. Smith, Mgr.

Iowa, Manson Lake—The Manson Light, Heating & Power Co. plans to change its d.c. generating system to a.c. in the spring. F. W. Mack, Mgr.

Iowa, Odebolt—The Odebolt Elec. Serv. Co. plans to build 30 mi. transmission farm lines and 12 mi. 6,600 volt transmission line to serve another town. H. E. Russell, Mgr.

Iowa, Sibley—The town plans to build a transmission line from here to Melvin. J. J. Shoemaker, City Hall, Supt.

Iowa, Sigourney—The Sigourney Electric Co. plans to double the capacity of its plant. H. L. Mann, Supt.

Iowa, Traer—The Traer Electric Plant plans to purchase a 400 hp. boiler in March and also construct a 40 mi., 2,300 volt transmission farm line extension. Edward Noyer, Mgr.

Iowa, Winterset—The Winterset Electric Light & Waterworks plans to change its entire d.c. generating system to a.c. Charles H. Smith, Supt.

Kan., Hiawatha—The Hiawatha Light, Power & Ice Co. is in the market for ice plant equipment and Diesel engine. Total estimated cost, $60,000.

Mont., Bridger—The Bridger Water & Light Co. plans to build 10 mi., 50,000 volt transmission line. J. S. Emmett, Secy.

Don't Overlook Opportunities!

You may find some of interest to you among the ads appearing in the

SEARCHLIGHT SECTION

Turn now to pages 91 to 101 for Every Business Want.

"Think Searchlight First"

PRICES--MATERIALS--SUPPLIES

These are prices to the power plant by jobbers in the larger buying centers east of the Mississippi. Elsewhere the prices will be modified by increased freight charges and by local conditions.

POWER-PLANT SUPPLIES

HOSE—

	Fire	50-Ft. Lengths
Underwriters' 2½-in.		75c. per ft.
Common, 2½-in.		40%

	Air		
	First Grade	Second Grade	Third Grade
¾-in. per ft.	$0.50	$0.33	$0.22

Steam—Discounts from List

First grade....30% Second grade...40% Third grade....45%

RUBBER BELTING—The following discounts from list apply to transmission rubber and duck belting:

Competition....65% Best grade....35%
Standard....50%

Note—Above discounts apply on new list issued July 1.

LEATHER BELTING—Present discounts from list in the following cities are as follows:

	Medium Grade	Heavy Grade
New York	45%	35%
St. Louis	40%	30%
Chicago	20%	10%
Birmingham	15%	15%
Denver	30%	20%

RAWHIDE LACING—20% for cut; 45c. per sq. ft. for ordinary.

PACKING—Prices per pound:

Rubber and duck for low-pressure steam	$1.00
Asbestos for high-pressure steam	1.70
Duck and rubber for piston packing	1.00
Flax, regular	1.20
Flax, waterproofed	1.70
Compressed asbestos sheet	.90
Wire insertion asbestos sheet	1.50
Rubber sheet	.50
Rubber sheet, wire insertion	.70
Rubber sheet, duck insertion	.50
Rubber sheet, cloth insertion	.30
Asbestos packing, twisted or braided and graphited, for valve stems and stuffing boxes	1.30
Asbestos wick, ½- and 1-lb. balls	.85

PIPE AND BOILER COVERING—Below are discounts and part of standard lists:

PIPE COVERING		BLOCKS AND SHEETS	
Pipe Size	Standard List Per Lin.Ft.	Thickness	Price per Sq.Ft.
1-in.	$0.27	½-in.	$0.27
2-in.	.36	1 -in.	.30
6-in.	.80	1½-in.	.45
4-in.	.60	2 -in.	.60
3-in.	.45	2½-in.	.75
8-in.	1.10	3 -in.	.90
10-in.	1.30	3½-in.	1.05
85% magnesia high pressure			List
For low-pressure heating and return lines		4-ply	50% off
		3-ply	52% off
		2-ply	54% off

GREASES—Prices are as follows in the following cities in cents per pound for barrel lots:

	Cincinnati	Pittsburgh	Chicago	St. Louis	Birmingham	Denver
Cup	7	9	6.6	6.7	8½	14½
Fiber or sponge	8	10	8.6	13	8½	18
Transmission	7	9	8.1	13	8½	17
Axle	4½	6	4.8	4.75	4½	5½
Gear	4½	9	6.1	7.5	8½	8
Car journal	22 (gal.)	21 (gal.)	4.7	4.7	8½	8

COTTON WASTE—The following prices are in cents per pound:

	New York		Cleveland	Chicago
	Current	One Year Ago		
White	13.00	11.00 to 13.00	14.00	11.00 to 14.00
Colored mixed	9.00 to 12.00	8.50 to 12.00	11.00	9.50 to 12.00

WIPING CLOTHS—Jobbers' price per 1000 is as follows:

	13½ x 13½	13½ x 20½
Cleveland	$52.00	$58.00
Chicago	41.00	43.50

LINSEED OIL—These prices are per gallon:

	New York		Cleveland	Chicago	
	Current	One Year Ago	Current	Current	One Year Ago
Raw in barrels (5 bbl. lots)	$1.80	$1.49	$2.50	$1.98	$1.66
5-gal. cans	2.00	1.74	2.75	2.23	1.86

WHITE AND RED LEAD—Base price per pound:

	Red				White	
	Current		1 Year Ago		Current	1 Yr. Ago
	Dry	In Oil	Dry	In Oil	Dry and In Oil	Dry and In Oil
100-lb. keg	14.50	16.00	13.00	14.50	14.50	13.00
25- and 50-lb. kegs	14.75	16.25	13.25	14.75	14.75	13.25
12½-lb. keg	15.00	16.50	13.50	15.00	15.00	13.50
1-lb. cans	16.50	18.00	.....	.....	16.50	15.00
5-lb. cans	17.50	19.00	.....	.....	17.50	16.00

500 lb. lots less 10% discount; 2000 lb. lots less 10-2½%.

RIVETS—The following quotations are allowed for fair-sized orders from warehouse:

	New York	Cleveland	Chicago
Steel ½ and smaller	40%	55%	45%
Tinned	40%	55%	45%

Boiler rivets, ½, ¾, 1 in. diameter by 2 in. to 5 in. sell as follows per 100 lb.:

New York..$5.00 Cleveland...$4.00 Chicago.....$4.97 Pittsburgh $4.72

Structural rivets, same sizes:

New York...$5.10 Cleveland...$4.10 Chicago.....$5.07 Pittsburgh $4.82

REFRACTORIES—Following prices are f. o. b. works, Pittsburgh:

Chrome brick	net ton	$75–80 at Chester, Penn.
Chrome cement	net ton	45–50 at Chester, Penn.
Clay brick, 1st quality fireclay	net M.	38–45 at Clearfield, Penn.
Clay brick, 2nd quality	net M.	33–35 at Clearfield, Penn.
Magnesite, dead burned	net ton	50–55 at Chester, Penn.
Magnesite brick, 9 x 4½ x 2½ in.	net ton	80–85 at Chester, Penn.
Silica brick	net M.	45–50 at Mt. Union, Penn.

Standard size fire brick, 9 x 4½ x 2½ in. The second quality is $4 to $5 cheaper per 1000.

St. Louis—Fire Clay, $35 to $50.
Birmingham—Silica, $50; fire clay, $45; magnesite, $80; chrome, $80.
Chicago—Second quality, $25 per ton.
Denver—Fire clay, $11 per ton.

BABBITT METAL—Warehouse prices in cents per pound:

	New York		Cleveland		Chicago	
	Current	One Year Ago	Current	One Year Ago	Current	One Year Ago
Best grade	90.00	87.00	74.50	80.00	70.00	75.00
Commercial	50.00	42.00	20.50	21.50	15.00	15.00

SWEDISH (NORWAY) IRON—The average price per 100 lb., in ton lots, is:

	Current	One Year Ago
New York	$21-26	$19.00
Cleveland	20.00	20.00
Chicago	16.50	19.00

In coils an advance of 50c. usually is charged.
Domestic iron (Swedish analysis) is selling at 15c. per lb.

SHEETS—Quotations are in cents per pound in various cities from warehouse; also the base quotations from mill:

	Mill Carloads Pittsburgh	New York		Cleveland	Chicago
		Current	One Year Ago		
No. 28 black	$4.35–4.85	$6.50–8.00	$6.52	$5.77	$6.00
No. 26 black	4.25–4.75	6.40–7.90	6.42	5.67	5.90
Nos. 22–24 black	4.20–4.71	6.35–7.35	6.37	5.62	5.85
Nos. 18–20 black	4.15–4.65	6.30–7.30	6.32	5.57	5.80
No. 16 blue annealed	3.75–3.20	6.02	5.72	5.17	5.02
No. 14 blue annealed	3.65–3.10	5.92	5.62	5.07	4.92
No. 10 blue annealed	3.55–4.00	5.50–6.00	5.52	4.97	4.82
No. 28 galvanized	5.70–6.20	7.50–9.00	7.77	7.12	7.25
No. 26 galvanized	5.40–5.90	7.20	7.47	6.82	6.95
No. 24 galvanized	5.25–5.75	7.05	7.32	6.57	6.52

PIPE—The following discounts are for carload lots, f. o. b. Pittsburgh; basing card of Jan. 1, 1919, for steel pipe and for iron pipe:

BUTT WELD

Inches	Steel Black	Steel Galvanized	Inches	Iron Black	Iron Galvanized
⅛, ¼ and ⅜	50½%	24%	½ to 1½	30½%	23½%
½	54½%	40%			
¾ to 3	57½%	44%			

LAP WELD

2	50½%	35%	2	32½%	18½%
2½ to 6	53½%	41%	2½ to 6	34½%	21½%

BUTT WELD, EXTRA STRONG PLAIN ENDS

⅛, ¼ and ⅜	48½%	29%	½ to 1½	39½%	24½%
½	51½%	39%			
¾ to 1½	50½%	43%			

LAP WELD, EXTRA STRONG PLAIN ENDS

2	48½%	37%	2	33½%	20½%
2½ to 4	51½%	49%	2½ to 4	35½%	23½%
4½ to 6	50½%	39%	4½ to 6	34½%	22½%

Stock discounts in cities named are as follows:

	New York		Cleveland		Chicago	
	Black	Galvanized	Black	Galvanized	Black	Galvanized
⅛ to 3 in. steel butt welded	47%	31%	43½%	34½%	57½%	44%
2½ to 3 in. steel lap welded	42%	27%	45½%	39½%	53½%	41%

Malleable fittings. Class B and C, from New York stock sell at list + 22½%.
Cast iron, standard sizes, 10-5% off.

BOILER TUBES—The following are the prices for carload lots, f. o. b. Pittsburgh:

Lap Welded Steel		Charcoal Iron	
3¼ to 4½ in.	40½	3½ to 4½ in.	15½
2¼ to 3¼ in.	30½	3 to 3½ in.	1
2½ in.	24	2½ to 2¾ in.	+ 1
1¼ to 2 in.	19½	2 to 2¼ in.	+16
		1¼ to 1¾ in.	+29

Standard Commercial Seamless—Cold Drawn or Hot Rolled

	Per Net Ton		Per Net Ton
1 in.	$327	1¼ in.	$207
1¼ in.	267	2 to 2½ in.	177
1½ in.	257	2¾ to 3¼ in.	167
1¾ in.	207	4 in.	187
		4½ to 5 in.	207

These prices do not apply to special specifications for locomotive tubes nor to special specifications for tubes for the Navy Department, which will be subject to special negotiations.

ELECTRICAL SUPPLIES

ARMORED CABLE—

B. & S. Size	Two Cond. M Ft	Three Cond. M Ft.	Two Cond. Lead M Ft.	Three Cond. Lead M Ft.
No. 14 solid	$104.00	$138.00	$164.00	$210.00
No. 12 solid	135.00	170.00	225.00	265.00
No. 10 solid	185.00	235.00	275.00	325.00
No. 8 stranded	285.00	375.00	520.00	500.00
No. 6 stranded	400.00	500.00	560.00	

From the above lists discounts are:

Less than coil lots	Net List
Coils to 1,000 ft.	10%
1,000 ft. and over	15%

BATTERIES, DRY—Regular No. 6 size red seal, Columbia, or Ever Ready:

	Each, Net
Less than 12	$0.45
12 to 50	.38
50 to 125 (bbl.)	.35
125 (bbl.) or over	.32

CONDUITS, ELBOWS AND COUPLINGS—Following are warehouse net prices per 1000 ft. for conduit and per 100 for couplings and elbows:

	Conduit		Elbows		Couplings	
Size, In.	Black 1,000 Ft. and Over	Galvanized 1,000 Ft. and over	Black 100 and Over	Galvanized 100 and Over	Black 100 and Over	Galvanized 1,100 and Over
⅜	$71.15	$76.25	$17.04	$18.18	$5.38	$5.74
½	71.15	76.25	17.04	18.18	6.25	6.70
¾	93.96	100.86	22.23	23.93	8.97	9.57
1	138.39	149.00	33.19	35.41	11.66	12.44
1¼	187.91	201.71	42.62	45.31	16.10	17.12
1½	224.68	241.18	56.82	60.62	19.89	21.15
2	302.29	324.49	104.17	110.77	26.52	28.20
2½	477.95	513.05	170.46	181.26	37.88	40.28
3	625.00	670.91	454.56	483.36	56.82	60.42
3½	779.24	834.44	1,003.82	1,067.42	75.76	80.56
4	945.03	1,010.43	1,160.08	1,233.57	94.70	100.70

5% cash 10 days.

From New York Warehouse—Less 5% cash.

Standard lengths rigid, 10 ft. Standard lengths flexible, ¼ in., 100 ft. Standard lengths flexible, ⅜ to 2 in., 50 ft.

CONDUIT NON-METALLIC, LOOM—

Size I. D., In.	Feet per Coil	List, Ft.	
3/16	250	$0.05½	
¼	250	.06	
⅜	250	.09	
½	200	.12	
⅝	200	.15	Coils.....45% off
¾	150	.18	Less coils, 35% off
1	100	.25	
1¼	100	.33	
1½	Odd lengths	.40	
2	Odd lengths	.55	

CUT-OUTS—Following are net prices each in standard-package quantities:

CUT-OUTS, PLUG

S. P. M. L.	$0.11	T. P. to D. P. S. B.	$0.24
D. P. M. L.	.11	T. P. to D. P. T. B.	.38
T. P. M. L.	.26	T. P. S. B.	.33
D. P. S. B.	.19	T. P. D. B.	.54
D. P. D. B.	.37		

CUT-OUTS, N. E. C. FUSE

	0-30 Amp.	31-60 Amp.	60-100 Amp.
D. P. M. L.	$0.33	$0.84	$1.68
T. P. M. L.	.48	1.20	2.40
D. P. S. B.	.42	1.05	....
T. P. S. B.	.81	1.80	....
D. P. D. B.	.78	2.10	....
T. P. D. B.	1.35	3.60	....
T. P. to D. P. D. B.	.90	2.52	....

FLEXIBLE CORD—Price per 1,000 ft. in coils of 250 ft.:

No. 18 cotton twisted	$22.00
No. 16 cotton twisted	27.00
No. 18 cotton parallel	26.50
No. 16 cotton parallel	34.50
No. 18 cotton reinforced heavy	34.00
No. 16 cotton reinforced heavy	42.00
No. 18 cotton reinforced light	30.00
No. 16 cotton reinforced light	36.75
No. 18 cotton Canvasite cord	28.50
No. 16 cotton Canvasite cord	32.00

FUSES, ENCLOSED—

250-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.25
35-amp. to 60-amp.	100	.35
65-amp. to 100-amp.	50	.90
110-amp. to 200-amp.	25	2.00
225-amp. to 400-amp.	25	3.60
425-amp. to 600-amp.	10	5.50

600-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.40
35-amp. to 60-amp.	100	.60
65-amp. to 100-amp.	50	1.50
110-amp. to 200-amp.	25	2.50
225-amp. to 400-amp.	25	5.50
450-amp. to 600-amp.	10	8.00

Discount: Less 1-5th standard package.....30%
1-5th to standard package.....40%
Standard package.....52%

FUSE PLUGS, MICA CAP—

0-30 ampere, standard package	$4.75C
0-30 ampere, less than standard package	6.00C

LAMPS—Below are present quotations in less than standard package quantities:

Straight-Side Bulbs				Pear-Shape Bulbs			
Mazda B— Watts	Plain	Frosted	No. in Package	Mazda C— Watts	Clear	Frosted	No. in Package
10	$0.35	$0.38	100	75	$0.70	$0.75	50
15	.35	.38	100	100	1.10	1.15	24
25	.35	.38	100	150	1.65	1.70	24
40	.35	.38	100	200	2.20	2.27	24
50	.35	.38	100	300	3.25	3.35	24
60	.40	.45	100	400	4.30	4.45	12
100	.85	.92	24	500	4.70	4.85	12
				750	6.50	6.75	8
				1000	7.50	7.75	8

Standard quantities are subject to discount of 10% from list. Annual contracts ranging from $150 to $300,000 net allow a discount of 17 to 40% from list.

PLUGS, ATTACHMENT—

	Each
Hubbell porcelain No. 5406, standard package 250	$0.24
Hubbell composition No. 5467, standard package 50	.32
Benjamin swivel No. 903, standard package 250	.20
Hubbell current taps No. 5638, standard package 50	.40

RUBBER-COVERED COPPER WIRE—Per 1000 ft. in New York.

No.	Solid Single Braid	Solid Double Braid	Stranded, Double Braid	Duplex
14	$12.00	$16.00	$13.90	$28.50
12	13.25	15.70	18.05	30.07
10	18.30	21.00	23.85	41.50
8	25.54	28.60	32.70	56.77
6	.....	.....	51.40	.....
4	.....	.....	70.00	.....
2	.....	.....	101.80	.....
1	.....	.....	131.86	.....
0	.....	.....	160.00	.....
00	.....	.....	193.50	.....
000	.....	.....	235.20	.....
0000	.....	.....	288.60	.....

Prices per 1000 ft. for Rubber-covered Wire in Following Cities:

	Denver			Birmingham		
	Single Braid	Double Braid	Duplex	Single Braid	Double Braid	Duplex
14	$11.25	$14.00	$31.00	$12.50	$15.39	$29.00
10	21.85	28.25	56.75	25.10	34.73	55.50
8	31.05	38.30	77.95	34.75	58.59	70.50
6	48.80	52.65	.....	57.50	82.11	.....
4	70.00	75.30	.....	81.65	95.50	.....
2	104.85	112.45	.....	.....	140.20	.....
1	136.85	146.15	.....	.....	190.90	.....
0	.....	194.25	.....	.....	231.33	.....
00	.....	239.60	.....	.....	281.23	.....
000	.....	294.00	.....	.....	343.22	.....
0000	.....	358.25	.....	.....	416.80	.....

Pittsburg—23c. base; discount 50% St. Louis—30c. base.

SOCKETS, BRASS SHELL—

¾ In. or Pendant Cap. Key, Each	Keyless, Each	Pull, Each	¾ In. Cap. Key, Each	Keyless, Each	Pull, Each
$0.33	$0.30	$0.60	$0.39	$0.36	$0.66

Less 1-5th standard package	+20%
1-5th to standard package	+10%
Standard package	—15%

WIRE, ANNUNCIATOR AND DAMPPROOF OFFICE—

No. 18 B. & S. regular spools (approx. 8 lb.)	45c. lb.
No. 18 B. & S. regular 1-lb. coils	46c. lb.

WIRING SUPPLIES—

Friction tape, ¾ in., less 100 lb. 50c. lb., 100 lb. lots	55c. lb.
Rubber tape, ¾ in., less 100 lb. 65c. lb., 100 lb. lots	60c. lb.
Wire solder, less 100 lb. 50c. lb., 100 lb. lots	46c. lb.
Soldering paste, 2 oz. cans Nokorode	$1.20 doz.

SWITCHES, KNIFE—

TYPE "C" NOT FUSIBLE

Size, Amp	Single Pole, Each	Double Pole. Each	Three Pole. Each	Four Pole, Each
30	$0.42	$0.68	$1.02	$1.36
60	.74	1.22	1.84	2.44
100	1.50	2.50	3.76	5.00
200	2.70	4.50	6.76	9.00

TYPE "C" FUSIBLE, TOP OR BOTTOM

30	.70	1.06	1.60	2.12
60	1.18	1.80	2.70	3.60
100	2.38	3.66	5.50	7.30
200	4.40	6.76	10.14	13.50

Discounts:

Less than $10.00 list value	+15%
$10 to $25 list value	list
$25 to $50 list value	— 5%
$50 to $200 list value	—10%
$200 list value or over	—15%